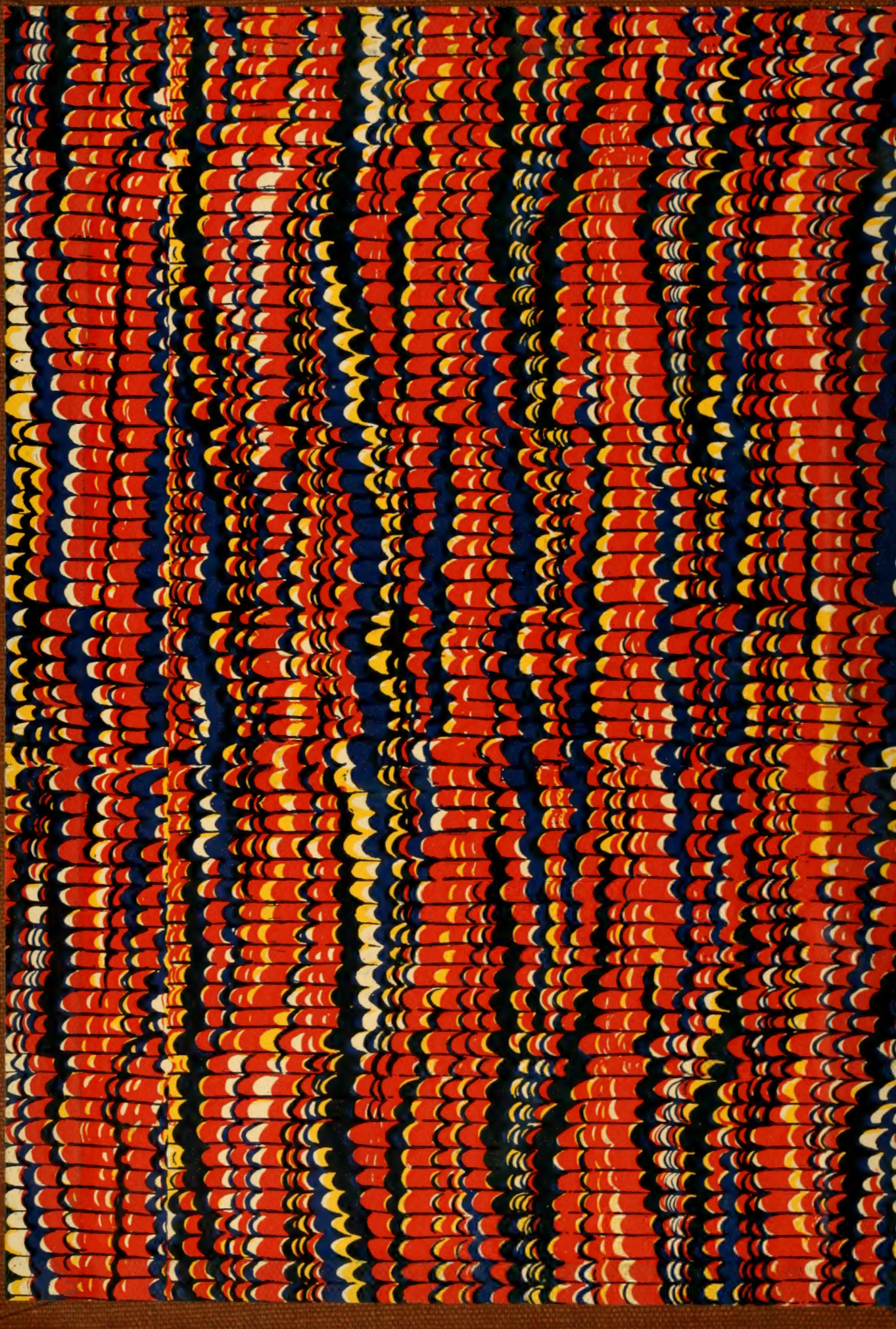

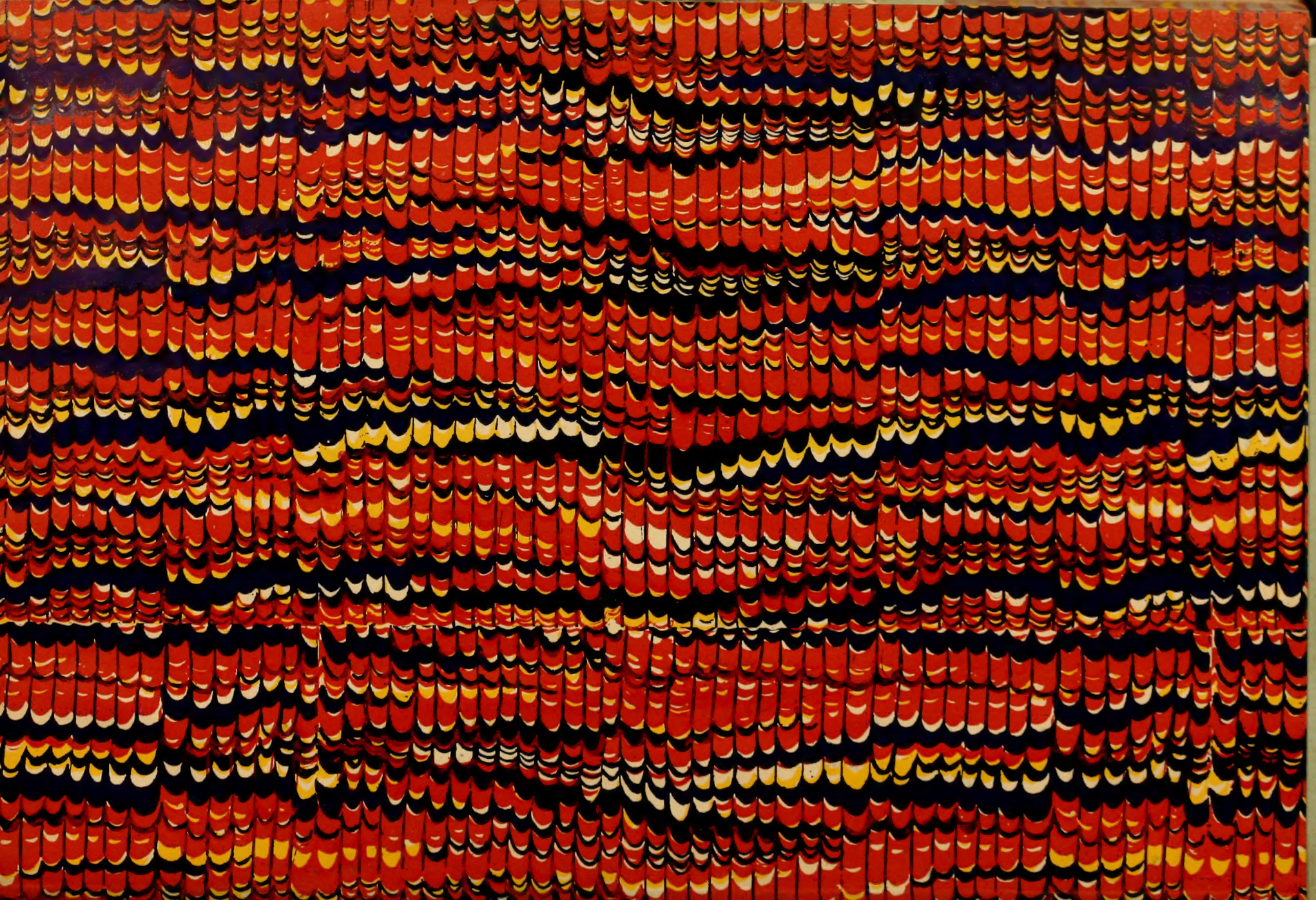

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MEMOIRS

OF THE

SCIENCE DEPARTMENT,

TOKIO DAIGAKU.

(University of Tokio.)

No. 7.

REPORT

ON THE

METEOROLOGY OF TOKIO.

FOR THE

YEAR 2540 (1880)

BY

T. C. MENDENHALL, PH. D.

PROFESSOR OF EXPERIMENTAL PHYSICS IN TOKIO DAIGAKU.

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TOKIO:

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REPORT ON THE METEOROLOGY OF TOKIO.

For the year 2540 (1880)

T. C. MENDENHALL.

PRELIMINARY.

In the report for the year 2539 (1879) the first of this series, the location of the observatory, in which the observations have been made, is given and the various instruments used are enumerated and described. It is, therefore, only necessary to state that no change has taken place in regard to either of these. As stated in that report, while the location of the observatory was satisfactory, the instrumental equipment was by no means so and it was at that time confidently expected that before the end of the year several important and much needed additions would be made. Unforseen difficulties have prevented this, however, and the observations of the year have been made with the instruments previously in use. Several very desirable additions and improvements were recommended in the conclusion of the report of last year and it is to be regretted that, up to the present time, it has not been found possible to make them. It is now proposed, however, to equip the observatory, during the next year, with an entirely new and complete set of apparatus, such as is in use in the first class stations of the Signal Service of the United States. Such an addition to the instruments already in use would add greatly to the value of the observations and it is sincerely hoped that nothing may interfere with its accomplishment.

During the year several changes have been made in the observers employed. When the hourly observations began in March, Mr Nobutani was added to the force and he has remained permanently attached to the observatory, taking the place of Mr Wuyeno. Mr Namba continued until August when, unfortunately for the interests of the observatory, he was ordered to France by the Educational Department, for the purpose of continuing his studies in Paris. Mr Namba was a careful and trustworthy observer and it is to be regretted that the observatory was so soon deprived of his services In his place Mr Kiriyama was appointed regularly and Mr Tsubota has also been employed during the months in which hourly observations have been maintained. Although, considering the interests of all parties concerned, the changes thus far made have been, on the

whole, desirable, it must be admitted that frequent changes, implying generally the introduction of inexperienced persons, cannot fail to be detrimental to the accuracy and value of the work and it is hoped they may be rare in the future.

The hours of observation for the year 1880 were the same as during the year 1879. With the beginning of the year 1881, however, the hours were changed and the number of daily observations increased to six. They are at present as follows; 6 a. m. 10 a. m. 2 p. m. 6 p. m. 9-27 p. m. and 11 p. m. The change from 10 p. m. to 9-27 p. m. was rendered necessary in order to make that observation agree with the "international hour" which has been changed in accordance with the desire of the chief of the U. S. Signal Service.

In the preparation of the report for this year the aim has been to arrange it that comparison between it and that for the previous year would be easy. The tables are, therefore, in general, arranged in the same manner and corresponding tables are indicated by the same letter of the alphabet. The charts are also given numbers corresponding to those of last year and comparison of these graphical representations of the meteorological phenomena for the two years will be easily made. Finally a series of charts is given, showing the means of a portion of the observations for the two years and a comparison of these with those for the present year is interesting as indicating a considerable degree of constancy on the part of several of the meteorological elements, that is, so far as can be established from the results of two years' observations. Hourly observations were maintained during the months of March, June, September and December. These four months, it is believed, afford a good representation of the varying meteorological conditions of the year, but it is intended to continue the hourly observations during several months of the year 1881.

During the first week in August an expedition to the summit of Fujinoyama was made by the special students in the Department of Physics, accompanied by Professor W. S. Chaplin of the Department of Civil Engineering, and the writer. The special object of the expedition was the determination of the force of gravity on the summit of the mountain. At the same time a series of meteorological observations was made during the stay of the party upon the mountain. The value of these has been greatly enhanced by the addition of a series of barometrical observations made at the same time by Messrs Nakamura and Wada of the Surveying Department who carried out a series of simultaneous observations on the summit of the mountain and at the sea level near the base. I am greatly indebted to Messrs Nakamura and Wada for their kindness in furnishing these observations to be made use of in this report in any desirable manner. Taken all together, these meteorological observations are, of course, of considerable value as affording a means of computing the height of the mountain. To that end Prof. Chaplin has kindly consented to discuss them in connection with others, bearing upon the same point, which he has been able to secure and the paper in which he has contributed the result of this discussion will be found to be one of the most interesting and valuable portions of this report.

In the report of last year reference was made to the proposed undertaking of a series of measurements of earth temperature, by means of the thermo-electric method. The labor of determining, experimentally, the best method for accomplishing this end was undertaken by Mr Hiraoka, Lecturer in the Department of Physics, and he has worked with great industry to overcome the difficulties which seemed to be in the way. Unfortunately complete success in that direction cannot yet be recorded. The chief and, apparently, only difficulty seems to be to secure sufficiently perfect insulation of the wires leading to the thermo-electric couples. It will be remembered that the ordinary means of insulation are not procurable in this country, or, if at all not without great difficulty. Various devices have been resorted to and in some instances success seemed assured, very satisfactory tests being obtained; but after a few days the insulation has broken down and temperature observations, therefore, rendered impossible. Success is by no means dispaired of, however, and efforts to secure it will still continue.

Reference was also made in the report of last year to a series of experiments about to be undertaken for the determination of the velocity of sound. It was proposed to take advantage of the signal gun, fired at 12 m. each day from Tenshudai and of the telegraph line connecting the observatory with the University. By the aid of the latter the time of the arrival of the sound at each of these points is recorded upon a chronograph in the physical laboratory at the University. This plan has been successfully carried out and observations to the number of more than two hundred have been already secured, giving the velocity of the sound wave under widely varying meteorological conditions. In addition to these, made, one each day, by means of the noon signal gun, a large number have recently been made, by means of successive firings upon the same day and, as nearly as possible, under the same meteorological conditions. These will greatly increase the value of the regular series and in the end, a result of considerable accuracy ought to be obtained from the reduction of thes observations. It has been thought best, however, to publish these results in a separate memoir, hence they do not appear in this report, as might be expected from what was said concerning them in the last.

A suggestion was also made concerning the use of some form of seismometer or seismograph in the meteorological observatory. Early in the year 1880 interest in seismology, quickened, doubtless, by the unusually violent earthquake of February 22, became so great that a society was formed in Tokio known as the "Seismological Society of Japan." This society is in good working condition. It has already published volumes of its proceedings and it is looking well after the interests of seismology in this country. It is desirable, therefore, that all observers co-operate with the society and it would be extremely useful to have one or more seismometers or seismographs, of a form which shall be approved by this society, placed in the meteorological observatory. For instruments which are not self-recording, or for those requiring frequent observation or attention,

this location would be especially favorable, owing to the continued presence of one or more observers.

The frequent occurrence of extensive and disastrous conflagrations in the City of Tokio has attracted the attention of all who have resided for any length of time in the capital. The immense destruction of property in this way within a year or two has excited great interest in all investigations pertaining to the origin of fires and possible means of preventing their spread. It has long been known that disastrous fires were most frequent, in general, in certain months of the year and it is easy to see that their occurrence is intimately related to the velocity and direction of the wind. Mr. Yamagawa, Adjunct Professor of Physics in the University, has recently devoted much time to an investigation of the origin and course of these fires, and to their classification in reference to atmospheric movement. The results of this investigation cannot fail to possess great interest and I am indebted to Professor Yamagawa for the preparation of some of the most important of these results, which will be found, with charts illustrating the conclusions reached, at the end of this volume.

BAROMETRICAL OBSERVATIONS.

Table A exhibits the readings of the barometer at all of the regular observations during the year, after having been reduced to the freezing point and to the level of the sea. The actual fluctuations in the barometer during the year are graphically exhibited on the six pages of Chart No I. A resumé of the observations contained in table A will be found in table B. In this will be found the means for each hour of observation for each month in the year, as well as general means, maxima and minima and range. Concerning the first it will be seen that the mean for the 2 p. m. readings is the least, and that, with few exceptions, the mean of the 7 a. m. is greater than those of 10 p. m. In the means for the year, that for the reading at 7 a. m. is .005 inches higher than that for the readings at 10 p. m. But a glance at either the table or chart, given under the head of "hourly observations," representing the means for each hour of the day, during the four months in which hourly observations were made, will show, of course, that a maximum does not occur at 7 a. m. but about three hours later, and that 2 p. m. is not, in general, a minimum point but that 10 p. m. represents very closely a second maximum. It is believed, therefore, that the hours of observation established for the year 1881 will furnish a much more truthful record of the barometrical changes.

A brief comparison of the principal facts found in table B and those from the corresponding table in the report for 1879 will be of interest.

	1880		1879	
Mean height of Barometer for the year..	29.958	inches	29.952	inches
Maximum.....	30.539	,,	30.513	,,
Minimum.....	29.178	,,	29.087	,,
Range.....	1.361	,,	1.426	,,
Maximum Monthly Range.....	1.276	,,	1.318	,,
Minimum ,, ,, ...	.554	,,	.389	,,

The maximum for this year occurred at 7 a. m. on February 26, while that for last year occurred in April. The minimum for this year was recorded at 7 a. m. on March 20 while that of last year was in February.

In regard to the maxima and minima given above, it must be remembered that they are derived from the series of regular observations. On occasions of extraordinary and rapid fluctuations in the barometer this series will often fail to contain the extreme points reached. Without doubt, the lowest point reached by the barometer during the year was touched at some time during the Typhoon of October 4th. At 2 O'clock a. m. of that day a height of 28.735 inches was observed. If this be compared with the maximum given above it greatly increases the range for the year, making it 1.804 inches instead of 1.361 as obtained from the regular series. Further reference to the barometrical fluctuations on that occasion will be found in the brief account of the typhoon given under "the wind."

The maximum monthly range for the year occurred in March while the greatest for last year was in February. The minimum fluctuation both for this year and for last was in July.

In Chart No 2 are exhibited, in the first diagram the fluctuation in the monthly barometric mean, and in the second the maximum, minimum and range for each month in the year. The curve in the first diagram shows three well marked maximum points, these being for the months of February, April and October and this will be found to agree with the results of last years' observations upon an examination of the corresponding diagram in the report for 1879. In the latter there is also a slight indication of a fourth maximum in the month of July, but this is not repeated in the curve for this year, the mean for July being lower than that for any other month.

TABLE A. SHOWING READINGS OF THE BAROMETER THROUGHOUT THE YEAR.

Day.	January			February			March			April		
	7	2	10	7	2	10	7	2	10	7	2	10
1	29.742	29.801	29.868	30.368	30.239	30.339	30.365	30.262	30.266	29.514	29.604	29.843
2	29.993	29.939	29.926	30.190	30.015	29.871	30.241	30.175	30.207	30.015	30.004	30.068
3	29.698	29.563	29.652	29.715	29.715	29.943	30.177	30.146	30.243	30.063	29.953	29.946
4	29.704	29.643	29.690	30.016	30.034	30.144	30.258	30.216	30.312	29.901	29.783	29.916
5	29.822	29.795	29.886	30.294	30.335	30.466	30.337	30.332	30.416	30.000	30.066	30.238
6	29.859	29.767	29.903	30.489	30.372	30.316	30.454	30.337	30.342	30.303	30.280	30.319
7	29.969	29.969	30.105	30.249	30.178	30.136	30.329	30.235	30.291	30.316	30.247	30.280
8	30.091	29.982	30.023	30.030	29.977	30.072	30.236	29.969	29.876	30.330	30.302	30.350
9	29.996	29.847	29.744	30.177	30.169	30.133	29.979	29.997	30.115	30.394	30.364	30.353
10	29.762	29.784	29.886	29.905	29.864	30.049	30.180	30.049	30.036	30.234	30.027	29.957
11	29.940	29.860	29.939	30.150	30.081	30.100	30.103	30.043	30.064	29.779	29.765	29.922
12	29.976	29.968	30.041	29.986	29.840	29.853	29.991	29.900	29.965	30.056	30.064	30.134
13	30.056	30.014	30.160	29.922	29.881	30.097	29.974	29.857	29.810	30.227	30.281	30.332
14	30.179	30.079	30.025	30.229	30.209	30.296	29.741	29.655	29.886	30.417	30.390	30.427
15	30.058	29.835	30.057	30.279	30.083	30.002	29.988	29.939	29.983	30.446	30.342	30.238
16	30.109	30.073	30.151	29.760	29.788	30.040	30.044	29.967	29.839	29.964	29.661	29.649
17	30.140	30.057	30.162	30.130	30.057	30.176	29.854	29.902	30.031	29.811	29.869	30.012
18	30.250	30.202	30.325	30.277	30.210	30.320	30.036	29.994	30.044	30.097	30.109	30.234
19	30.342	30.287	30.331	30.383	30.341	30.213	30.027	29.888	29.574	30.336	30.309	30.330
20	30.410	30.352	30.430	29.881	29.821	29.908	29.178	29.355	29.891	30.345	30.283	30.294
21	30.370	30.192	30.023	29.904	29.800	29.752	30.113	30.173	30.302	30.332	30.232	30.245
22	29.865	29.917	30.142	29.914	29.905	30.042	30.357	30.258	30.234	30.194	30.066	29.923
23	30.244	30.140	30.251	30.111	30.099	30.269	30.025	29.800	29.747	29.689	29.510	29.457
24	30.364	30.323	30.380	30.312	30.220	30.284	29.846	29.927	30.066	29.486	29.430	29.525
25	30.346	30.089	29.995	30.481	30.483	30.535	30.091	29.941	29 988	29.572	29.637	29.922
26	29.739	29.570	29.826	30.539	30.444	30.474	30.038	30.005	29.988	30.099	30.105	30.119
27	30.032	30.004	30.046	30.384	30.198	30.014	29.934	29.809	29.767	30.120	30.011	29.941
28	30.146	30.147	30.218	29.649	29.751	29.985	29.654	29.715	29.983	29.825	29.857	29.974
29	30.296	30.143	30.174	30.196	30.231	30.355	30.079	29.927	29.643	30.101	30.085	30.100
30	30.314	30.285	30.389	.....	.....	.....	29.735	29.881	30.033	30.032	29.868	29.599
31	30.442	30.387	30.399	.....	.....	.....	29.976	29.672	29.415	.....	.....	.....

TABLE A. SHOWING READINGS OF THE BAROMETER THROUGHOUT THE YEAR.

Day.	May.			June.			July.			August.		
	7	2	10	7	2	10	7	2	10	7	2	10
1	29.698	29.671	29.897	29.608	29.620	29.653	29.656	29.697	29.694	29.868	29.813	29.837
2	30.100	30.130	30.215	29.655	29.688	29.837	29.619	29.697	29.830	29.836	29.781	29.820
3	30.214	30.094	30.083	29.905	29.896	29.949	29.892	29.901	29.951	29.849	29.814	29.900
4	30.054	29.999	29.995	29.956	29.909	29.963	30.004	29.963	29.957	29.925	29.911	29.946
5	29.993	29.943	29.949	29.970	29.940	29.995	29.894	29.821	29.842	29.962	29.919	29.957
6	29.925	29.780	29.665	30.009	29.952	29.927	29.858	29.798	29.801	29.962	29.924	29.979
7	29.449	29.552	29.836	29.532	29.291	29.342	29.735	29.653	29.705	29.994	29.966	29.946
8	29.985	29.995	30.009	29.521	29.505	29.645	29.704	29.674	29.717	29.958	29.957	29.948
9	30.038	29.941	29.925	29.703	29.681	29.750	29.716	29.676	29.732	29.934	29.872	29.878
10	29.835	29.791	29.642	29.816	29.837	29.867	29.764	29.743	29.817	29.858	29.762	29.766
11	29.709	29.779	29.925	29.907	29.900	29.918	29.797	29.759	29.784	29.683	29.608	29.581
12	29.993	29.879	29.877	29.923	29.882	29.865	29.764	29.731	29.750	29.530	29.465	29.481
13	29.823	29.742	29.780	29.860	29.828	29.901	29.793	29.777	29.872	29.570	29.595	29.691
14	29.789	29.736	29.839	29.959	29.927	29.981	29.920	29.928	30.005	29.757	29.745	29.796
15	29.906	29.883	29.950	29.991	29.918	29.928	30.049	30.000	30.031	29.852	29.849	29.922
16	29.958	29.936	29.897	29.842	29.739	29.627	30.023	29.969	29.998	29.934	29.929	29.984
17	29.802	29.785	29.911	29.603	29.607	29.678	29.952	29.900	29.909	29.982	29.938	29.985
18	30.033	30.033	30.139	29.677	29.646	29.675	29.896	29.829	29.839	29.993	29.940	29.956
19	30.208	30.196	30.189	29.691	29.684	29.736	29.821	29.769	29.779	29.957	29.930	29.955
20	30.139	30.055	30.115	29.765	29.760	29.827	29.761	29.726	29.759	29.945	29.885	29.923
21	30.044	29.949	29.910	29.935	29.999	30.103	29.731	29.583	29.707	29.895	29.818	29.847
22	29.723	29.710	29.765	30.179	30.204	30.252	29.642	29.561	29.554	29.821	29.761	29.744
23	29.769	29.720	29.786	30.279	30.224	30.205	29.533	29.495	29.601	29.761	29.711	29.728
24	29.863	29.813	29.818	30.167	30.098	30.022	29.666	29.639	29.686	29.730	29.683	29.734
25	29.863	29.783	29.806	29.917	29.813	29.770	29.702	29.666	29.687	29.786	29.699	29.401
26	29.867	29.868	29.983	29.776	29.758	29.857	29.658	29.621	29.663	29.568	29.645	29.731
27	30.093	30.062	30.104	29.892	29.852	29.866	29.715	29.704	29.782	29.749	29.724	29.714
28	30.090	29.971	29.988	29.836	29.773	29.786	29.767	29.653	29.632	29.689	29.673	29.662
29	29.995	29.940	29.928	29.782	29.707	29.731	29.701	29.725	29.836	29.714	29.759	29.923
30	29.927	29.846	29.853	29.745	29.683	29.712	29.888	29.893	19.905	30.024	30.004	30.034
31	29.801	29.748	26.647	.....	.....	.....	29.932	29.886	29.884	30.000	29.927	29.932

TABLE A. SHOWING READINGS OF THE BAROMETER THROUGHOUT THE YEAR.

Day.	September			October			November			December		
	7	2	10	7	2	10	7	2	10	7	2	10
1	29.954	29.942	30.003	30.183	30.077	30.073	30.053	29.979	30.011	30.007	29.966	29.960
2	30.033	30.009	30.066	29.973	29.907	29.943	29.960	29.860	29.917	29.980	29.924	30.085
3	30.092	30.033	30.067	29.793	29.582	29.356	29.942	29.908	30.028	30.116	30.046	30.066
4	30.052	29.975	29.995	29.464	29.768	29.958	30.068	30.000	30.041	29.991	29.867	29.932
5	29.977	29.977	29.988	29.972	29.928	30.141	30.060	30.003	30.113	29.943	29.856	29.901
6	29.962	29.938	29.937	30.297	30.337	30.378	30.133	30.134	30.111	29.961	29.968	30.108
7	29.952	29.888	29.934	30.378	30.293	30.303	29.975	29.917	29.854	30.102	30.012	30.014
8	30.008	29.970	30.027	30.237	30.152	30.094	29.788	29.683	29.844	29.905	29.719	29.650
9	30.053	29.977	29.972	30.029	29.952	29.987	29.811	29.716	29.897	29.536	29.371	29.443
10	29.886	29.772	29.807	30.013	30.017	30.180	29.940	29.951	30.158	29.482	29.476	29.578
11	29.840	29.829	29.874	30.278	30.221	30.277	30.260	30.248	30.286	29.658	29.661	29.857
12	29.990	29.997	30.097	30.165	30.015	30.035	30.340	30.244	30.206	30.023	30.049	30.177
13	30.113	30.069	30.112	30.183	30.249	30.303	30.174	30.108	30.037	30.223	30.152	30.168
14	30.081	30.005	30.004	30.295	30.225	30.259	29.921	29.885	30.029	30.093	29.932	29.817
15	29.951	29.856	29.856	30.209	30.121	30.112	30.103	30.080	30.164	29.803	29.739	39.789
16	29.701	39.690	29.869	30.093	30.023	30.059	30.238	30.110	30.115	29.772	29.859	30.059
17	30.014	30.013	30.080	30.062	30.014	30.058	30.067	29.979	30.028	30.105	30.066	30.107
18	30.073	30.018	30.077	30.022	29.916	29.928	30.003	29.891	29.964	30.089	29.979	29.965
19	30.060	29.998	30.034	29.966	29.956	30.073	30.111	30.054	30.079	29.849	29.731	29.805
20	30.001	29.910	29.924	30.099	30.053	30.093	29.961	29.820	29.852	29.894	29.889	29.976
21	29.886	29.803	29.801	30.102	30.101	30.203	29.849	29.799	29.889	29.919	29.789	29.957
22	29.815	29.783	29.786	30.176	30.053	30.041	30.015	29.993	30.043	29.895	29.789	29.929
23	29.711	29.646	29.819	29.949	29.865	29.896	29.918	29.771	29.831	29.875	29.736	29.773
24	30.051	30.112	30.221	29.875	29.846	29.975	29.906	29.845	29.923	29.831	29.880	30.128
25	30.238	30.154	30.134	30.009	29.942	29.955	29.988	29.911	29.899	30.158	30.088	30.041
26	30.031	29.905	29.890	29.812	29.590	29.706	29.746	29.453	29.558	30.099	30.088	30.173
27	30.058	30.095	30.161	29.872	29.955	30.097	29.540	29.471	29.684	30.113	29.913	29.818
28	30.131	29.980	29.964	30.148	30.104	30.128	29.821	29.882	30.016	29.739	29.798	30.015
29	29.971	29.955	30.043	30.105	30.016	30.023	30.110	30.049	30.029	30.049	30.030	30.184
30	30.145	30.121	30.214	29.925	29.748	29.677	29.957	29.864	29.969	30.283	30.289	30.448
31	.....	.....	.....	29.816	29.839	29.993	.....	.....	.....	30.440	30.342	30.293

TABLE B. SHOWING MONTHLY MEANS, MAXIMA, MINIMA AND RANGE OF THE BAROMETER FOR THE YEAR.

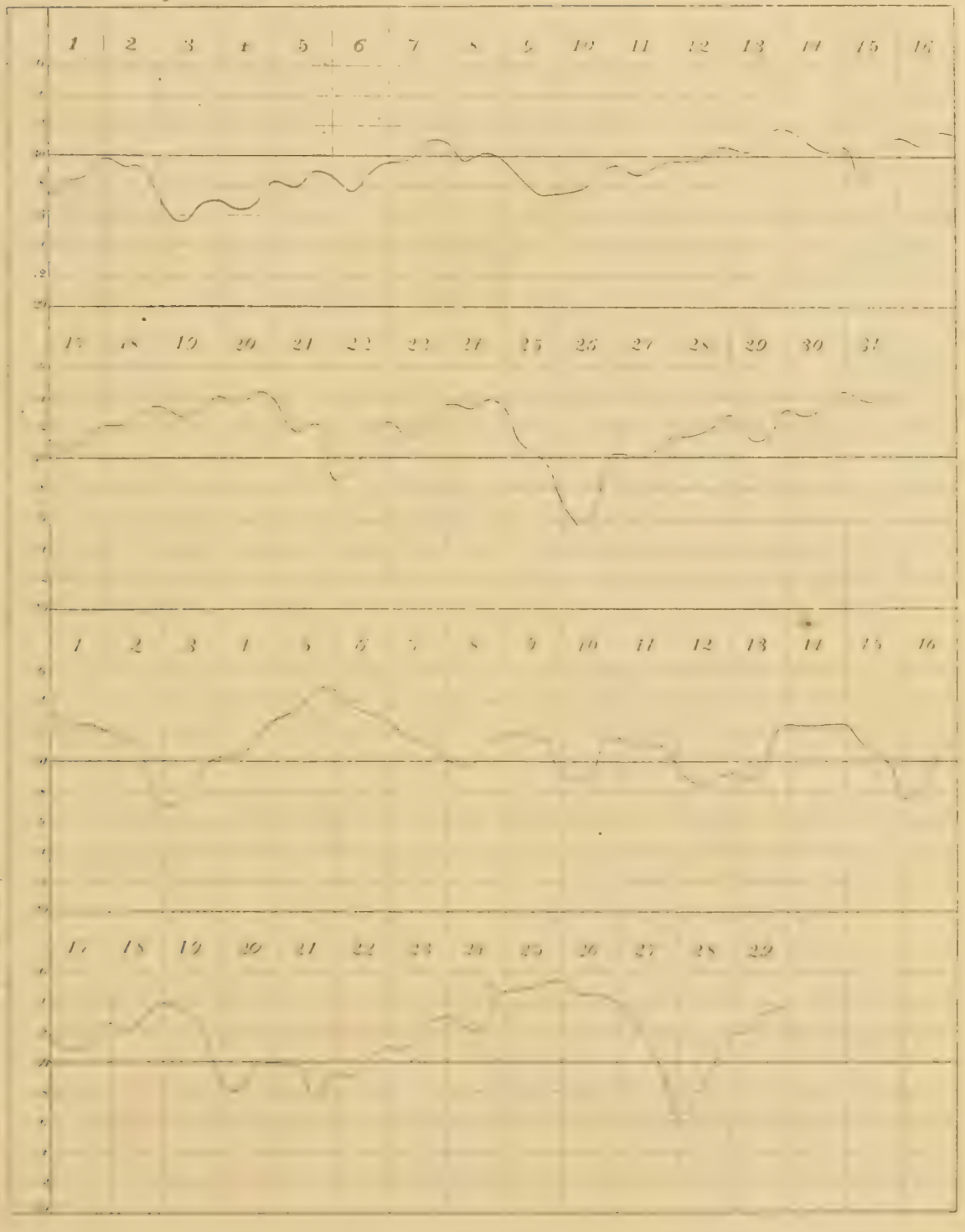
Month.	Means of Each Reading.			General Means.	Max.	Min.	Range.
	7 a.m.	2 p.m.	10 p.m.				
January	30.073	30.000	30.069	30.047	30.442	29.563	.879
February	30.135	30.081	30.144	30.120	30.539	29.649	.890
March	30.043	29.978	30.012	30.011	30.454	29.178	1.276
April	30.067	30.017	30.055	30.046	30.446	29.430	1.016
May	29.925	29.882	29.917	29.908	30.215	29.449	.766
June	29.817	29.811	29.845	29.831	30.279	29.291	.988
July	29.792	29.756	29.797	29.782	30.049	29.495	.554
August	29.841	29.807	29.829	29.826	30.031	29.401	.630
September	29.991	29.947	29.992	29.978	30.238	29.646	.592
October	30.048	29.996	30.042	30.029	30.378	29.356	1.022
November	29.992	29.920	29.986	29.966	30.340	29.453	.887
December	29.961	29.903	29.974	29.947	30.418	29.371	1.077
Year	29.977	29.925	29.972	29.958	30.539	29.178	1.361

Chart No 1

Showing Fluctuations in the Barometer during the Year 2540(1880)

第一號圖

表明一千八百八十年四季晴雨計昇降之情



Jan. 月

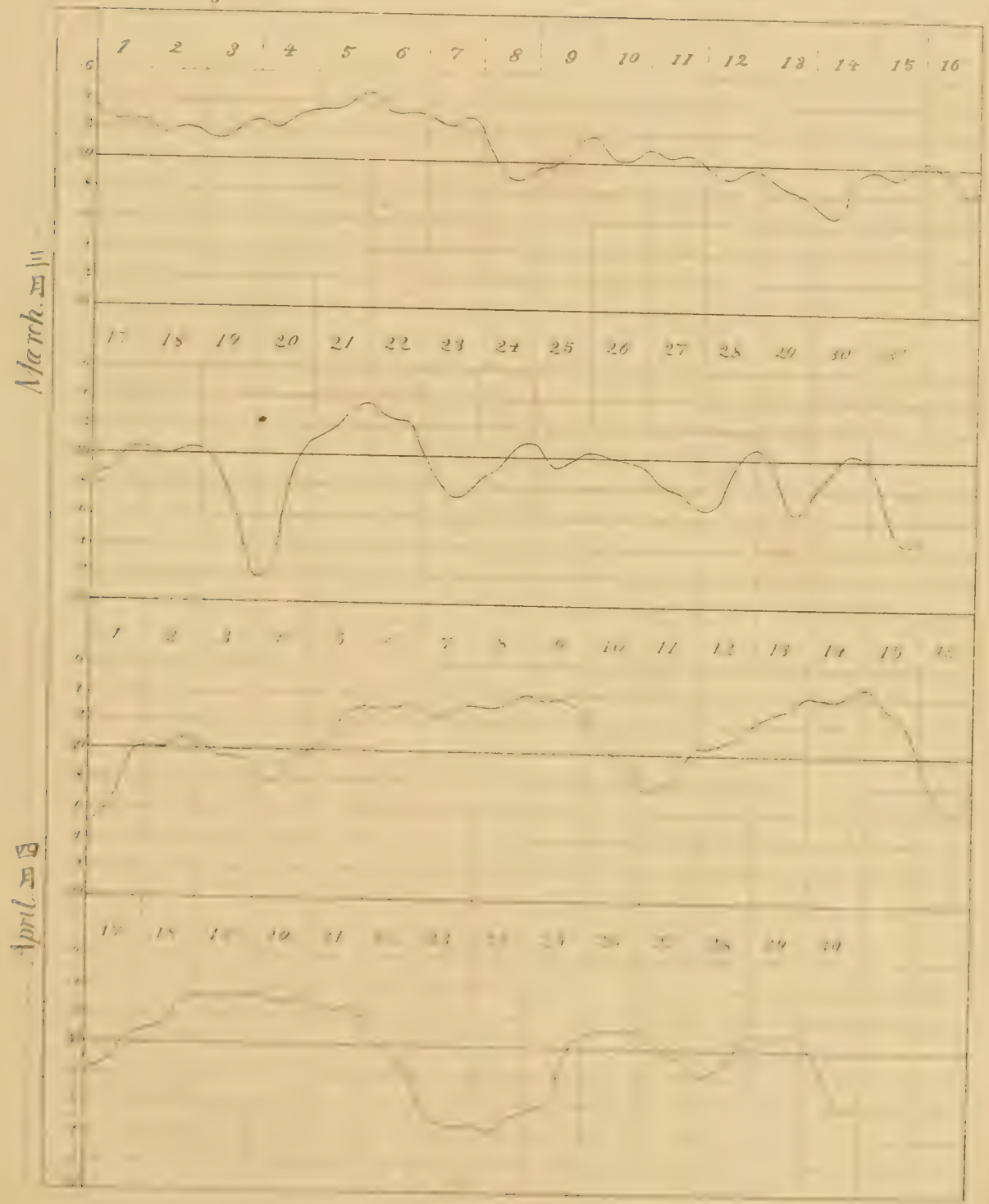
Feb. 二月

Chart No 1

Showing Fluctuations in the Barometer during the Year 2540 (1880)

第一圖

紀元二千五百四十年(明治十年)中晴雨計昇降之圖



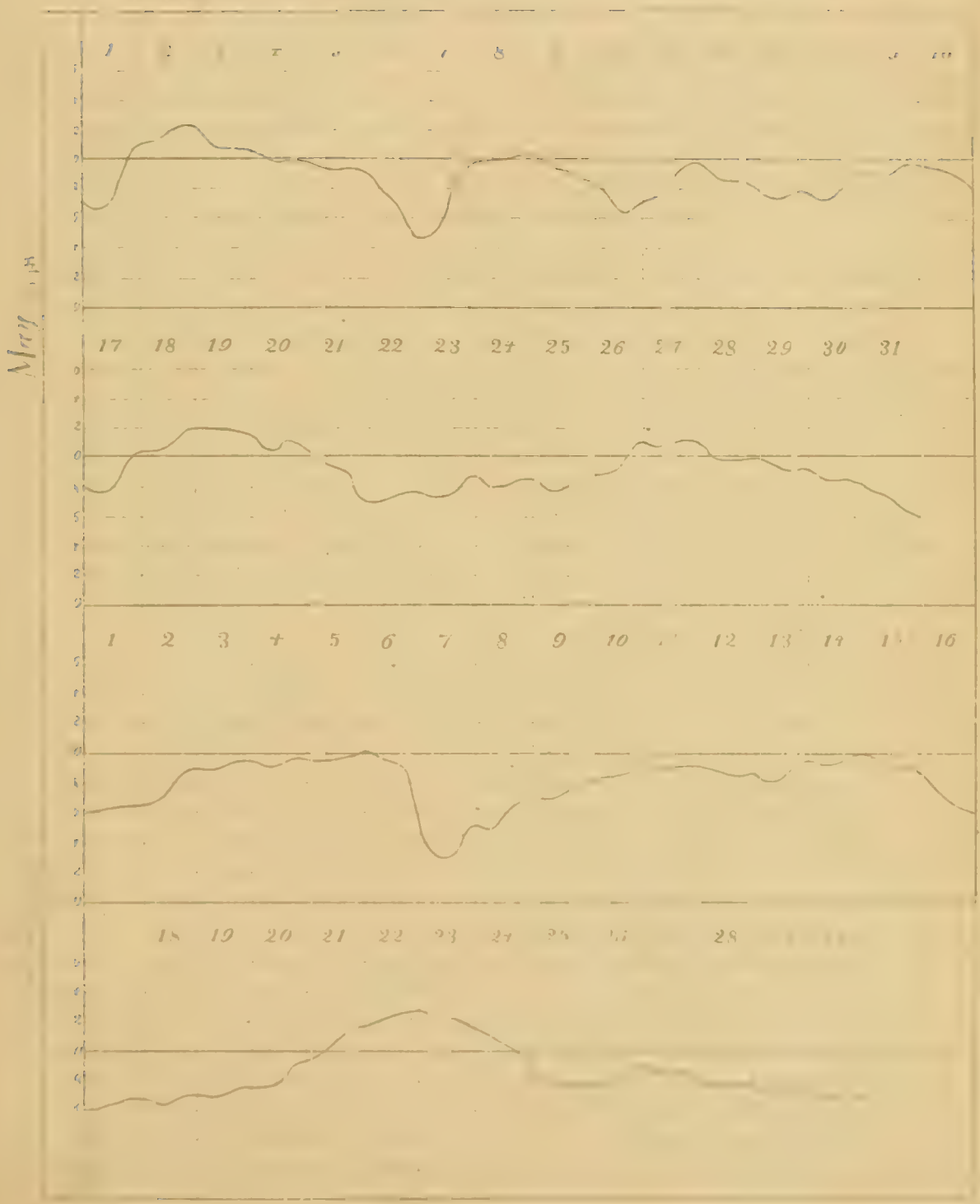

17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
1 2 3 4 5 6 7 8 9 10 12 13 14 16
18 19 20 21 22 28

Chart No 1

Showing Fluctuations in the Barometer during the Year 25-10-1880

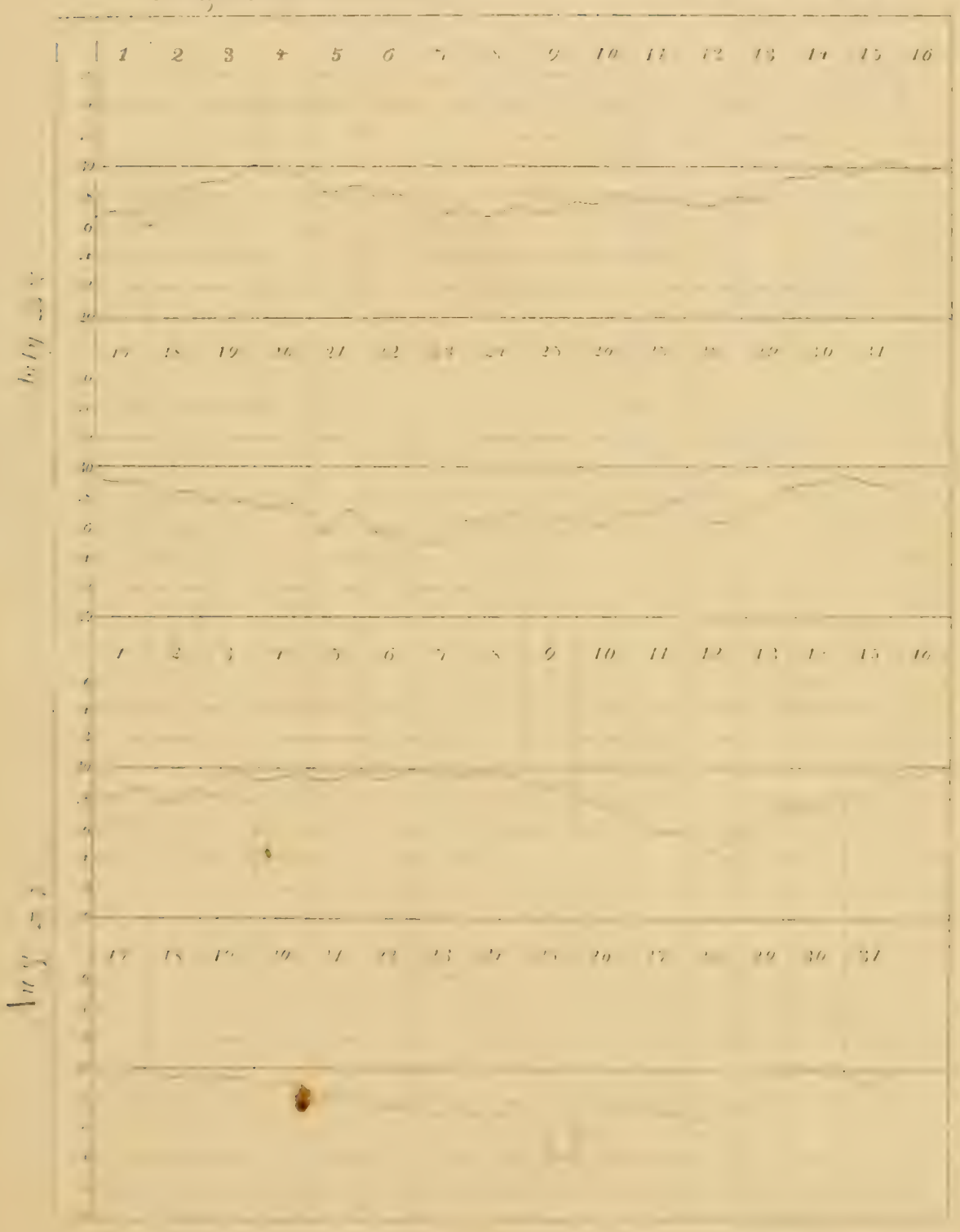


Chart No1

Showing Fluctuations in the Barometer during the Year 2540(1880)

第一圖

紀元二千五百四十年(西曆一千八百八十年)三月晴雨計昇降

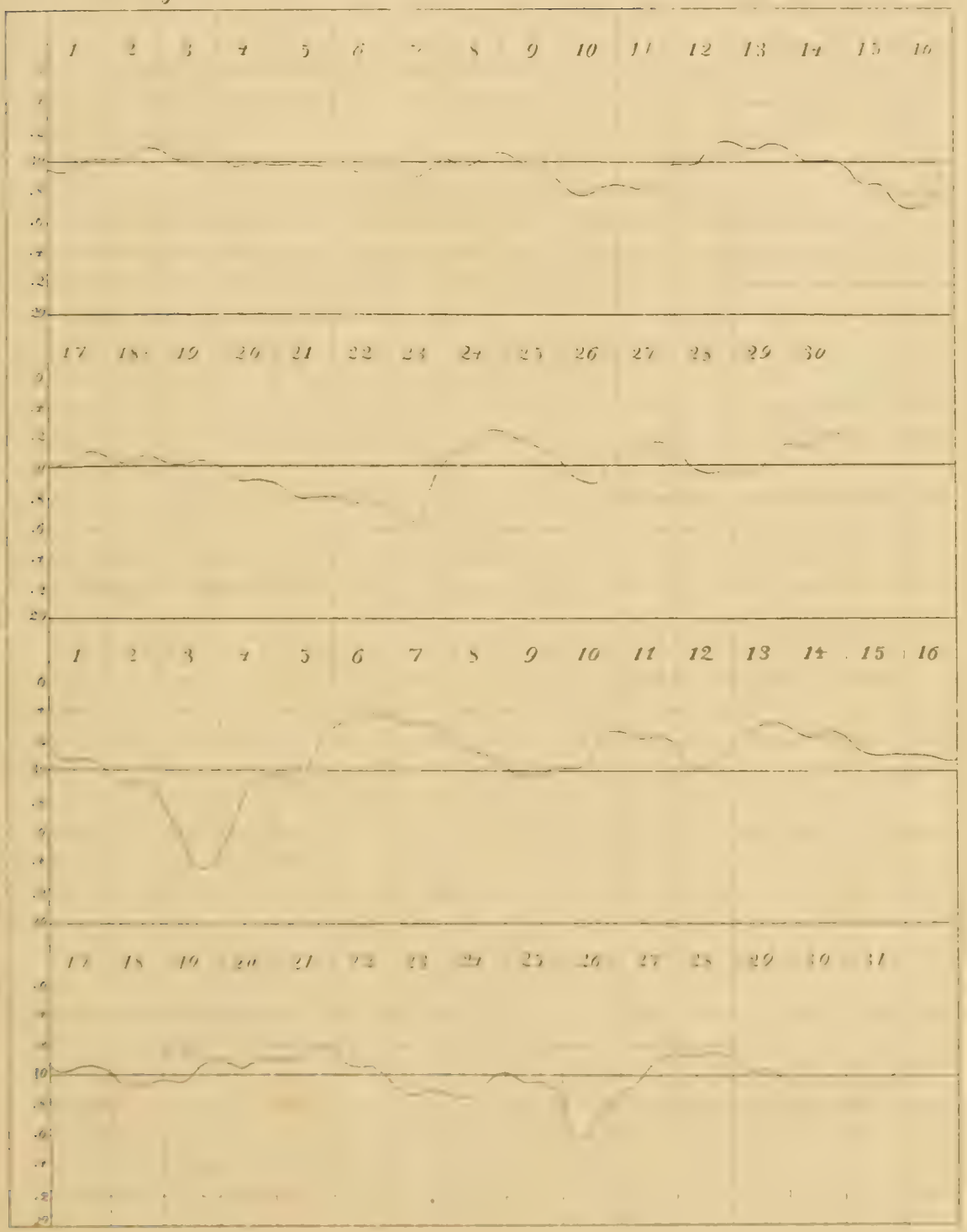
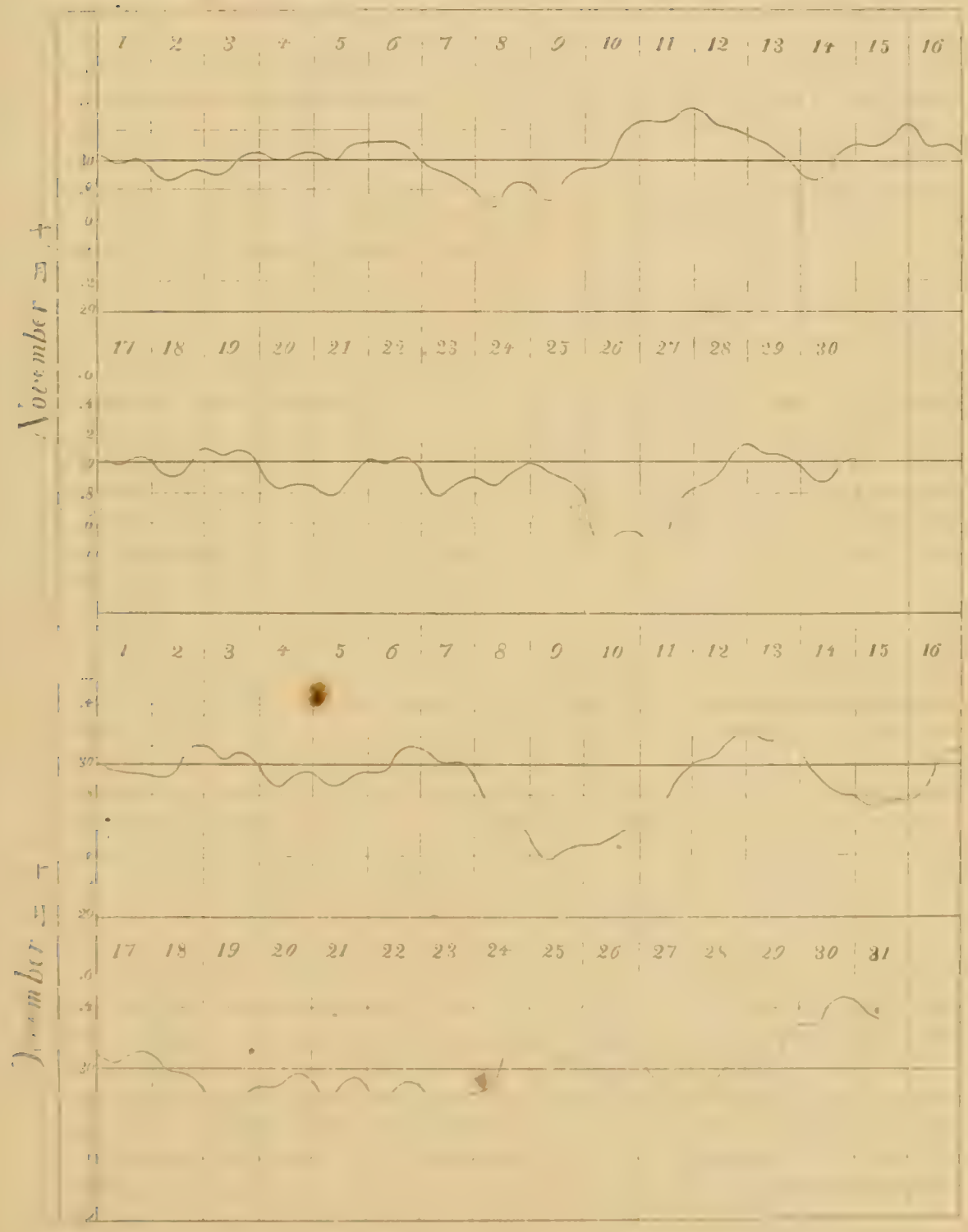


Chart N°1

Showing Fluctuations in the Barometer during the Year 2510(1880)

第一圖

光緒五年庚辰歲晴雨表昇降圖

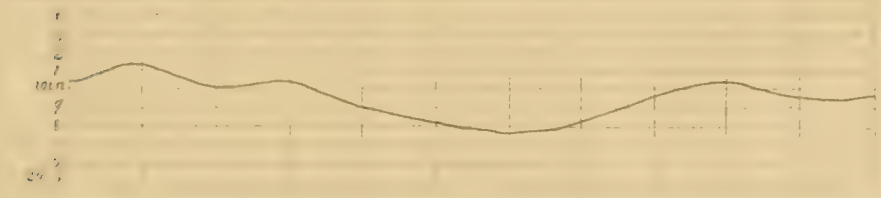


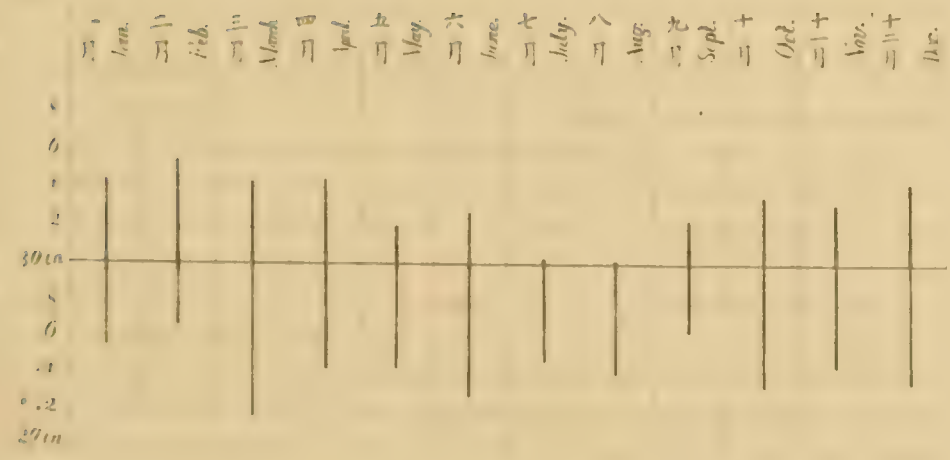
Chorrl N°2

Showing
1st Mean height of the Barometer for each month,
2nd Maximum, Minimum and Range for each month, during the Year 2540(1880)

第一 紀元二千五百四十年(明治十三年)各月中晴雨計平均度ノ畨
二 第二 同年各月中晴雨計最高最低度并ニ昇降限畨ノ畨

一月 Jan. 二月 Feo. 三月 Mch. 四月 Apl. 五月 May. 六月 June. 七月 July. 八月 Aug. 九月 Sept. 十月 Oct. 十一月 Nov. 十二月 Dec.





TEMPERATURE.

Table C contains all the regular readings of the standard thermometer during the year, and from this table Chart No 3 is constructed, showing the fluctuations in temperature throughout the year. In table D will be found the maximum and minimum temperatures for every day in the year, the mean of the readings of the standard thermometer and also the mean of the maximum and minimum temperatures for each day.

The following is a comparison of extreme temperatures in the year 1880 with those of the previous year.

A minimum of 32° or under was observed as follows;

	1880	1879
In January on	29 days	27 days
„ February	12 „	13 „
„ March	8 „	4 „
„ November	1 „	1 „
„ December	22 „	5 „
Total for the year	72 „	50 „

A maximum temperature of 90° or over was observed as follows;

	1880	1879
In July	0 days	7 days
„ August	2 „	5 „
Total for the year	2 „	12 „

It will thus be seen that the temperature during the year has been, on the whole, lower than during the year previous. In the general means the difference amounts to 1°.2, that for this year being 57°.3 and that for 1879 58°.5.

Table F contains monthly means, maxima, minima etc., collected from the previous tables. If it be compared with the corresponding table for the previous year it will be seen that for several months the means for the two years agree very closely, the principal difference occurring during the last four months. During the months of September, October and November the temperature was higher than during the same time in the previous year but in December a sudden fall occurs. In 1879 the difference between the November and December means was 2°.8, in 1880 it was 11°.3. The minimum temperature for 1879 occurred in January; that for 1880 occurred in December. A low temperature continued to prevail in January 1881 and the winter of 1880-81 must be regarded as one of unusual severity. It must also be noticed that lower temperatures prevailed during July and August of this year than during the same months of the year 1879.

The highest temperature reached during 1880 was 96°.5 on August 21st and only on one other day was as high a temperature as 90° recorded, whereas in 1879 the highest point reached was 93° and a record of 90° or higher was made on 12 days of that year.

The lowest temperature for the year was 22°.3 which was reached on December 25th and also on December 29th. The lowest point reached in 1879 was 24°.1. The total range for the year 1880 was 68°.2 and for the year 1879 it was 68°.9.

The highest minimum temperature for any month was 65° in August, the minimum for the same month of last year being 69°.4. The greatest daily range in the year was 30°.4 on December 22, the maximum daily range for 1879 being 29°.8. The minimum daily range was 1°.4 on March 2, that for 1879 being 3°. During the whole twenty four hours of March 2 the temperature differed from that of freezing by barely 1° and again on the whole of July 5 it did not differ from 70° by more than 2°.

In Chart No 4 the curve of monthly means of the standard thermometer is shown in the first diagram. In the second the maximum, minimum and range for each month and in the third the maximum and minimum daily range for each month are exhibited. In their general features these diagrams will be found, of course, to resemble those of last year very closely.

TABLE C. SHOWING READINGS OF STANDARD THERMOMETER.

Day.	January			February			March			April		
	7	2	10	7	2	10	7	2	10	7	2	10
1	36.0	50.5	37.0	32.6	39.5	39.4	29.0	43.0	38.3	44.0	59.4	45.2
2	29.2	46.0	41.5	32.0	51.5	42.0	32.0	32.3	31.9	40.6	55.8	45.1
3	30.5	49.5	40.0	32.7	57.5	40.0	28.8	40.3	35.3	35.8	41.0	39.4
4	34.5	49.0	34.7	37.0	41.8	37.0	30.0	41.0	36.3	39.3	49.0	44.5
5	31.0	47.5	34.5	32.7	41.0	33.7	32.5	42.5	36.2	43.2	56.8	47.8
6	29.0	44.7	34.0	29.0	37.0	38.0	30.2	46.5	42.7	41.7	50.4	44.0
7	25.6	44.5	33.2	38.6	44.5	41.8	34.5	51.9	46.7	42.7	59.8	53.4
8	28.0	46.6	34.5	41.6	44.2	39.0	41.0	48.5	40.5	45.0	64.2	55.0
9	27.5	43.0	35.3	36.0	39.5	37.5	37.0	51.9	48.0	50.5	61.0	54.1
10	36.7	45.0	37.7	38.9	51.8	32.8	36.4	57.5	48.9	47.5	69.3	63.1
11	34.0	48.0	37.8	41.0	46.8	43.8	43.8	56.0	48.0	64.8	59.3	56.7
12	34.5	47.0	34.7	42.0	47.0	46.0	42.5	57.0	49.7	50.5	49.0	47.8
13	27.3	46.4	33.4	39.6	50.8	39.0	39.5	59.0	50.9	45.4	50.0	47.8
14	27.9	41.5	30.7	36.5	53.2	42.4	43.5	61.0	45.2	47.7	57.6	47.9
15	29.7	43.7	32.0	35.4	59.4	46.8	37.0	60.8	49.5	47.1	55.5	52.0
16	30.6	42.0	32.7	46.0	60.5	46.0	39.6	57.2	50.0	50.9	53.8	53.8
17	24.4	43.5	32.8	40.0	41.8	41.0	49.0	67.5	57.5	51.3	55.0	50.0
18	28.4	41.5	30.2	38.5	48.5	44.0	52.0	59.0	56.0	45.0	56.8	51.0
19	30.8	38.9	33.5	36.8	35.0	35.2	54.0	65.0	60.6	47.8	60.7	54.4
20	29.6	42.5	35.0	38.7	53.0	50.2	60.2	52.0	37.1	51.0	63.5	55.4
21	30.1	36.0	33.7	46.0	50.0	44.7	36.7	51.7	44.7	52.8	64.5	59.0
22	34.0	46.2	34.5	40.0	45.0	38.9	40.0	54.7	49.1	54.5	65.0	60.5
23	32.0	49.7	31.8	33.0	44.0	34.0	45.5	51.0	44.8	57.5	65.7	61.2
24	27.0	38.5	27.5	30.3	41.0	38.0	39.5	45.7	38.0	60.1	72.7	57.8
25	24.8	41.0	31.5	31.0	41.8	35.0	33.6	55.6	45.6	55.2	58.5	49.5
26	29.8	45.7	35.9	29.0	48.0	44.8	43.0	62.8	52.3	46.5	61.0	55.5
27	29.0	44.4	32.0	42.0	51.5	48.0	43.0	64.4	54.7	52.0	65.4	62.0
28	28.0	46.5	34.6	47.7	63.0	45.5	56.5	65.9	46.8	65.5	70.2	61.0
29	29.0	44.9	34.3	34.0	37.8	35.0	44.0	57.0	41.2	57.0	61.0	53.5
30	29.8	41.5	32.3	.....	.....	.....	46.0	57.5	49.0	49.5	54.3	53.5
31	30.5	42.7	35.6	.....	.....	.....	41.9	48.1	44.7	.....	.....	.....

TABLE C. SHOWING READINGS OF STANDARD THERMOMETER.

Day.	May			June			July			August		
	7	2	10	7	2	10	7	2	10	7	2	10
1	59.0	68.5	57.6	61.1	61.0	60.0	67.4	70.0	68.4	77.7	89.5	81.5
2	56.5	70.5	59.4	57.5	62.0	60.0	66.0	77.0	70.8	77.2	88.2	79.8
3	53.9	70.1	62.0	59.4	65.9	61.0	67.8	70.0	69.3	79.6	85.6	77.4
4	56.0	64.1	60.5	61.1	74.5	66.1	69.1	79.2	71.6	75.8	85.7	78.2
5	54.5	71.4	62.0	60.5	77.4	67.4	70.3	71.0	69.3	79.1	87.8	78.9
6	59.4	70.1	64.9	63.0	78.0	71.0	68.5	78.3	74.0	75.2	84.6	79.0
7	52.6	57.8	48.8	69.8	79.2	71.8	73.5	82.3	78.3	78.7	84.7	76.8
8	48.5	64.1	58.5	70.1	81.0	70.7	76.4	84.8	78.0	77.8	77.3	75.0
9	53.5	73.5	63.3	67.0	75.5	68.0	77.0	85.0	75.2	75.1	78.8	76.4
10	61.1	61.5	60.3	65.1	76.5	69.3	73.8	82.5	76.8	77.7	82.9	75.3
11	64.0	77.1	62.2	66.9	69.3	65.0	75.3	83.7	78.0	72.0	82.5	76.9
12	59.3	71.0	61.5	64.4	73.1	65.5	78.0	85.5	78.2	74.2	77.0	75.2
13	57.0	70.8	66.5	65.9	75.3	65.4	77.8	82.8	73.7	72.3	84.8	77.4
14	61.8	68.6	61.0	66.0	75.6	68.0	73.0	76.0	73.5	79.0	83.0	76.9
15	55.1	66.4	59.2	62.5	78.6	69.8	75.5	80.9	74.0	79.3	88.8	78.4
16	52.4	61.3	52.5	70.0	69.4	62.1	74.0	81.0	72.6	79.4	84.2	78.2
17	55.3	69.3	61.8	65.0	77.0	69.1	73.8	81.9	73.5	78.4	85.0	78.5
18	57.0	74.7	63.0	65.8	66.0	64.8	71.8	83.0	73.9	73.7	81.9	76.3
19	59.0	69.3	64.0	64.5	70.0	64.6	73.9	81.9	73.0	74.8	82.2	74.7
20	58.7	74.0	64.6	62.1	67.2	61.1	71.0	80.5	74.0	71.2	83.1	75.6
21	60.5	71.8	65.0	59.0	62.8	62.5	73.0	75.2	69.4	74.9	84.2	75.7
22	63.6	63.0	60.0	63.4	68.8	65.3	67.4	76.3	73.0	72.8	85.9	78.3
23	65.5	74.5	65.0	64.5	73.6	66.0	71.0	83.8	75.9	76.0	85.9	78.2
24	64.0	74.6	66.5	63.7	67.8	60.5	76.5	83.6	74.2	75.0	89.9	81.0
25	62.4	76.0	66.5	61.5	66.3	65.1	73.0	76.8	74.7	80.9	84.8	77.3
26	61.2	82.0	66.2	66.0	77.2	68.3	74.2	80.0	76.5	80.4	88.4	77.9
27	62.0	77.5	68.2	68.0	79.0	70.4	75.5	83.0	76.9	76.3	77.7	72.9
28	65.8	77.0	68.3	69.9	77.9	70.3	76.3	77.6	74.3	70.4	80.0	73.4
29	69.9	75.8	66.7	68.0	80.3	72.5	77.0	84.2	79.7	70.0	79.3	68.9
30	63.6	78.0	68.1	71.0	79.6	73.2	78.4	85.8	78.9	70.0	78.9	73.0
31	65.7	67.3	67.5	.....	.....	.....	79.5	88.7	80.0	71.2	70.5	66.0

TABLE C. SHOWING READINGS OF STANDARD THERMOMETER.

Day.	September.			October.			November.			December.		
	7	2	10	7	2	10	7	2	10	7	2	10
1	65.4	72.0	68.2	57.7	68.0	62.0	43.9	59.9	52.3	34.0	55.5	44.6
2	67.3	78.0	68.0	62.0	67.0	63.5	52.0	65.1	55.1	36.5	57.8	42.4
3	64.7	77.3	70.0	62.1	69.0	70.2	47.7	61.8	53.0	37.6	53.6	41.3
4	66.3	78.8	73.4	68.8	72.6	65.0	46.6	65.5	55.9	33.6	53.4	40.8
5	70.5	68.4	67.5	59.0	75.5	62.3	46.8	66.9	54.0	32.5	46.5	34.3
6	66.3	73.0	71.0	56.0	60.5	57.2	52.3	56.8	53.8	38.1	48.8	37.2
7	70.0	81.4	74.0	57.1	67.5	60.7	49.0	63.8	53.1	28.0	48.6	35.7
8	70.3	84.5	74.8	58.6	66.2	58.0	43.1	63.9	45.3	31.5	49.6	37.8
9	71.3	79.8	72.8	54.8	72.3	63.0	38.2	61.5	45.0	32.2	52.5	35.6
10	73.3	82.2	76.5	55.5	72.7	62.2	36.8	58.4	43.0	30.5	46.0	32.3
11	73.1	82.5	77.4	54.7	70.6	60.3	36.8	57.5	44.9	32.8	53.4	38.8
12	69.0	80.1	73.2	61.5	62.1	60.3	45.0	50.0	50.0	36.7	54.0	43.4
13	67.6	82.2	75.4	59.9	63.9	58.4	49.0	48.4	46.5	36.4	54.0	41.4
14	71.5	81.2	75.3	51.3	69.1	62.4	47.4	60.2	51.0	30.0	50.7	41.8
15	71.6	82.2	75.4	54.4	71.3	63.3	44.0	64.5	52.8	39.6	45.0	37.6
16	77.0	77.0	69.2	56.6	70.0	64.1	42.4	60.5	49.0	30.3	41.0	34.8
17	65.1	76.9	67.9	59.0	69.4	61.9	40.3	59.8	49.0	31.5	51.0	36.8
18	64.2	77.0	71.0	55.1	69.6	62.6	40.6	58.8	47.9	35.0	48.2	35.3
19	69.2	79.4	72.8	55.1	69.1	59.9	42.0	61.8	52.5	31.5	48.8	38.6
20	70.1	79.9	74.5	53.7	63.5	58.9	44.1	56.3	49.0	32.0	46.7	34.5
21	69.0	82.1	76.0	55.7	69.2	57.1	44.0	60.5	47.9	26.9	44.2	36.2
22	71.7	82.3	77.0	53.9	64.4	61.0	41.0	59.5	51.3	25.4	53.8	36.4
23	76.0	88.2	78.1	59.0	64.2	59.5	45.5	48.5	42.5	36.7	44.8	36.0
24	68.5	73.4	64.0	59.3	68.8	58.5	37.5	57.0	45.6	32.5	38.5	27.7
25	61.5	75.0	67.2	53.9	69.5	60.1	39.0	56.0	45.4	26.8	44.0	32.3
26	65.9	70.3	70.5	60.9	70.0	55.0	38.9	60.9	46.8	24.2	45.0	31.5
27	65.0	72.6	61.2	53.7	69.5	60.8	41.5	59.0	45.2	24.4	46.7	36.2
28	55.4	75.0	68.8	54.7	66.6	60.4	43.5	53.5	45.4	30.4	39.8	30.0
29	61.2	73.2	64.1	55.4	70.0	59.6	35.7	51.8	42.0	23.0	45.0	31.6
30	54.9	71.4	61.5	52.2	67.5	57.8	32.9	56.5	43.4	34.1	46.1	34.8
31	.....	.....	.....	50.5	59.4	48.2	.....	.....	.....	26.0	42.4	31.8

TABLE D. GIVING MAXIMA, MINIMA AND MEAN TEMPERATURES FOR THE YEAR.

Day.	January				February				March				April			
	Max.	Min.	M.	m.	Max.	Min.	M.	m.	Max.	Min.	M.	m.	Max.	Min.	M.	m.
1	51.0	33.5	41.2	42.2	40.9	30.4	35.8	35.6	43.7	28.0	36.8	35.8	59.4	39.0	49.5	49.2
2	47.4	28.0	38.9	37.7	54.5	30.4	41.8	42.4	32.3	30.9	32.1	31.6	56.0	39.4	47.2	47.7
3	52.9	28.5	43.0	40.7	61.5	31.8	43.4	46.6	41.0	28.0	34.8	34.5	45.7	35.0	39.7	40.3
4	49.3	33.0	39.4	41.1	43.7	32.0	38.6	37.8	42.1	29.4	35.8	35.7	51.2	37.8	44.3	44.5
5	47.5	26.5	37.7	37.0	43.0	31.0	35.8	37.0	43.7	30.8	37.1	37.2	59.5	40.0	49.3	49.7
6	45.2	27.5	35.9	36.3	39.3	27.0	34.7	33.1	47.4	29.0	38.8	38.2	51.2	40.6	45.4	45.9
7	44.8	23.5	34.4	34.1	44.8	28.8	41.4	36.8	53.5	31.5	44.4	42.5	59.8	39.0	52.0	49.4
8	46.5	25.0	36.2	35.7	44.4	37.5	41.6	40.9	44.0	39.8	41.7	41.9	64.2	43.4	54.7	53.8
9	44.0	27.0	35.3	35.5	39.8	35.4	37.7	37.6	52.5	36.3	45.6	44.4	63.6	46.0	55.2	54.8
10	46.2	27.2	39.8	36.7	51.8	30.5	41.2	41.1	58.0	35.4	47.6	46.7	69.3	46.1	60.0	57.7
11	48.7	26.5	39.9	37.6	46.9	38.0	43.9	42.4	56.5	43.0	49.8	49.7	71.3	55.6	60.3	63.4
12	47.5	31.8	38.7	39.6	48.5	40.5	45.0	44.5	57.9	41.5	49.7	49.7	56.7	46.6	49.1	51.6
13	47.0	26.8	35.7	36.9	52.8	38.0	42.9	45.4	59.0	38.0	49.8	48.5	50.0	44.0	47.7	47.0
14	42.2	26.5	33.4	34.3	55.5	35.8	44.0	45.6	63.7	42.3	49.9	53.0	58.0	43.6	51.1	50.8
15	44.7	26.8	35.1	35.7	62.9	34.6	47.2	48.7	63.0	35.8	49.1	49.4	58.3	44.0	51.5	51.1
16	42.7	28.9	34.9	35.8	63.4	35.3	50.8	49.3	57.6	37.8	48.9	47.7	53.8	50.0	52.8	51.9
17	47.5	23.5	33.6	35.5	43.5	39.3	40.9	41.4	68.0	47.8	58.0	57.9	55.5	49.6	52.1	52.5
18	41.5	25.0	33.4	33.2	48.5	37.5	43.7	43.0	63.0	51.0	55.7	57.0	56.8	43.5	50.9	50.1
19	39.3	27.5	34.4	33.4	37.8	34.0	35.7	35.9	66.8	53.0	59.9	59.9	60.8	42.5	54.3	51.6
20	42.8	28.0	35.7	35.4	54.4	36.5	47.3	45.4	61.6	34.9	49.8	48.2	64.2	46.1	56.6	55.1
21	37.0	29.3	33.3	33.1	51.0	44.0	46.9	47.5	53.0	33.8	44.4	43.4	69.0	46.0	58.8	57.5
22	46.9	30.0	38.2	38.4	45.8	37.4	41.3	41.6	55.2	38.4	47.9	46.8	67.5	53.0	60.0	60.2
23	49.9	31.4	37.8	40.6	44.4	31.4	37.0	37.9	55.8	43.5	47.1	49.6	68.0	56.2	61.5	62.1
24	40.2	26.0	31.0	33.1	44.8	27.3	36.4	36.0	47.0	37.0	41.1	42.0	72.7	56.5	63.5	64.6
25	42.0	23.0	32.4	32.5	42.5	29.4	35.9	35.9	57.0	30.5	44.9	43.7	60.0	49.0	54.4	54.5
26	47.0	25.0	37.1	36.0	51.2	26.4	40.6	38.8	63.9	38.6	52.7	51.2	61.1	40.2	54.3	50.6
27	47.0	28.0	35.1	37.5	53.0	40.5	47.2	46.7	64.5	41.0	54.0	52.7	65.5	51.0	59.8	58.2
28	46.5	27.4	36.4	36.9	64.0	45.0	52.1	54.5	66.0	52.4	56.4	59.2	73.5	60.2	65.6	66.8
29	45.8	26.6	36.1	36.2	40.1	33.0	35.6	36.5	57.0	40.0	47.4	48.5	61.5	53.5	57.2	57.5
30	43.0	27.8	34.5	35.4	...	...	...	...	58.2	39.6	50.8	48.9	55.4	48.5	52.4	51.9
31	44.0	29.0	36.3	36.5	...	...	...	...	49.0	40.4	43.2	44.7	...	...	...	...

TABLE D. GIVING MAXIMA, MINIMA AND MEAN TEMPERATURES FOR THE YEAR.

Day.	May				June				July				August			
	Max.	Min.	M.	m.	Max.	Min.	M.	m.	Max.	Min.	M.	m.	Max.	Min.	M.	m.
1	68.5	50.8	61.7	59.6	61.7	59.0	60.7	60.3	70.0	67.0	68.6	68.5	90.2	74.5	82.9	82.3
2	70.5	50.0	62.1	60.2	64.5	56.3	59.8	60.4	78.0	64.4	71.3	71.2	88.5	74.7	81.7	81.6
3	70.1	50.5	62.0	60.3	67.8	57.7	62.1	62.7	71.0	67.0	69.0	69.0	85.6	75.0	80.9	80.3
4	64.1	54.5	60.2	59.3	74.9	59.2	67.2	67.0	79.2	66.8	73.3	73.0	86.2	71.5	79.9	78.8
5	71.4	51.4	62.6	61.4	77.6	57.5	68.4	67.5	72.0	68.5	70.2	70.2	87.8	73.9	81.9	80.8
6	71.2	57.5	64.8	64.3	78.3	59.0	70.7	68.6	78.8	66.0	73.6	72.4	85.3	71.9	79.6	78.6
7	65.0	48.7	53.1	56.8	79.2	68.8	73.6	74.0	83.0	72.0	78.0	77.5	84.7	73.0	80.1	78.8
8	64.5	42.5	57.0	53.5	81.0	63.2	73.9	72.1	84.8	70.0	79.7	77.4	82.1	74.0	76.7	78.0
9	74.2	52.0	63.4	63.1	76.5	64.0	70.2	70.2	85.0	74.0	79.1	79.5	80.0	73.7	76.8	76.8
10	63.8	59.4	61.0	61.6	77.0	62.5	70.3	69.7	83.5	71.9	77.7	77.7	83.4	72.0	78.6	77.7
11	77.8	54.6	67.8	66.2	69.6	64.3	67.1	66.9	86.3	73.0	79.0	79.6	82.9	68.5	77.1	75.7
12	71.0	53.0	63.9	62.0	73.0	62.5	67.6	67.7	85.7	75.0	80.6	80.3	79.4	72.7	75.5	76.0
13	74.1	55.0	64.8	64.5	75.3	62.4	68.9	68.8	82.9	71.8	78.1	77.3	84.8	67.5	78.2	76.1
14	69.0	59.0	63.8	64.0	75.7	59.0	69.9	67.3	78.9	69.1	74.2	74.0	83.7	73.0	79.6	78.3
15	67.5	52.0	60.2	59.7	78.6	61.9	70.3	70.2	81.2	70.6	76.8	75.9	88.8	71.1	82.2	79.9
16	62.0	51.2	55.4	56.6	72.2	61.3	67.2	66.7	81.5	70.8	75.9	76.1	84.4	75.6	80.6	80.0
17	70.0	51.3	62.1	60.6	77.3	59.8	70.4	68.5	82.2	65.0	76.4	73.6	85.0	74.8	80.6	79.9
18	75.0	51.0	64.9	63.0	69.5	64.0	65.5	66.7	83.5	66.5	76.2	75.0	83.4	70.4	77.3	76.9
19	69.3	56.5	64.1	62.9	70.9	63.7	66.4	67.3	82.1	66.1	76.3	74.1	82.5	72.8	77.2	77.6
20	74.0	54.6	65.8	64.3	67.7	60.5	63.5	64.1	80.8	66.5	75.2	73.6	83.6	69.1	76.6	76.3
21	72.7	54.5	65.8	63.6	65.5	57.9	61.4	61.7	75.3	68.4	72.5	71.8	84.3	71.3	78.3	77.8
22	65.8	58.0	62.2	61.9	72.1	60.5	65.8	66.3	77.4	65.4	72.2	71.4	86.9	68.5	79.0	77.7
23	74.5	59.0	68.3	66.7	73.7	61.0	68.0	67.3	84.2	68.5	76.9	76.3	86.1	73.0	80.0	79.5
24	75.0	59.5	68.4	67.2	68.0	60.0	64.0	64.0	83.6	70.9	78.1	77.2	90.5	71.8	82.0	81.1
25	76.5	56.5	68.3	66.5	66.3	58.0	64.3	62.1	76.8	70.5	74.8	73.6	86.7	74.8	81.0	80.7
26	82.0	55.4	69.8	68.7	78.0	63.0	70.5	70.5	81.1	72.7	76.9	76.9	88.4	76.1	83.2	82.2
27	78.0	59.5	69.2	68.7	80.0	65.0	72.5	72.5	83.8	73.1	78.5	78.4	78.8	69.6	75.6	74.2
28	77.0	62.4	70.4	69.7	78.0	68.0	72.7	73.0	78.5	73.4	76.1	75.9	80.4	68.7	74.6	74.5
29	75.8	64.5	70.8	70.1	80.3	66.6	73.6	73.4	84.2	73.5	80.3	78.8	80.0	67.7	72.7	73.8
30	78.3	59.3	69.9	68.8	79.6	69.0	74.6	74.3	85.9	77.2	81.0	81.5	78.9	65.0	74.0	71.9
31	69.0	62.5	66.8	65.7	...	...	...	...	88.7	77.3	82.7	83.0	73.0	65.0	69.2	69.0

TABLE D. GIVING MAXIMA, MINIMA AND MEAN TEMPERATURES FOR THE YEAR.

Day.	September				October				November				December			
	Max.	Min.	M.	m.	Max.	Min.	M.	m.	Max.	Min.	M.	m.	Max.	Min.	M.	m.
1	75.4	63.8	68.5	69.6	69.0	55.8	62.6	62.4	60.9	42.3	52.0	51.6	56.0	32.3	44.7	44.1
2	78.4	65.9	71.1	72.1	67.7	60.0	64.2	63.8	66.2	49.6	57.4	57.9	57.9	34.5	45.6	46.2
3	77.6	63.3	70.7	70.4	70.2	60.5	67.1	65.3	68.2	45.0	54.2	56.6	53.9	36.0	44.2	44.9
4	80.4	63.2	72.8	71.8	73.6	57.7	68.8	65.6	66.9	45.5	56.0	56.2	53.9	31.5	42.6	42.7
5	73.4	66.2	68.8	69.8	76.0	57.0	65.6	66.5	68.0	45.5	55.9	56.7	48.0	30.5	37.8	39.2
6	73.1	65.1	70.1	69.1	62.5	55.0	57.9	58.7	57.0	51.4	54.3	54.2	50.2	33.2	41.4	41.7
7	82.0	68.1	75.1	75.0	67.8	55.6	61.8	61.7	64.6	47.6	55.3	56.1	49.5	26.8	37.4	38.1
8	85.1	66.5	76.5	75.8	69.7	56.0	60.9	62.8	65.9	42.1	50.8	54.0	49.9	30.0	39.6	39.9
9	81.1	69.3	74.6	75.2	72.6	52.9	63.4	62.7	63.1	35.0	48.2	49.0	53.1	29.0	40.1	41.0
10	84.3	70.1	77.3	77.2	72.9	54.0	63.5	63.4	58.9	35.0	46.1	46.9	49.2	26.3	36.3	37.7
11	84.6	71.2	77.7	77.9	72.1	53.1	61.9	62.6	57.9	35.0	46.4	46.4	54.3	29.1	41.7	41.7
12	81.0	66.9	74.1	73.9	62.8	58.1	61.3	60.4	51.1	42.1	48.3	46.6	54.8	34.3	44.7	44.5
13	83.0	65.4	75.1	74.2	64.4	56.7	60.7	60.5	50.3	45.0	48.0	47.6	54.6	35.5	43.9	45.0
14	82.5	69.2	76.0	75.8	69.2	49.5	60.9	59.3	60.6	43.7	52.9	52.1	52.1	29.0	40.8	40.5
15	83.1	70.0	76.4	76.5	71.7	54.4	63.0	63.0	65.0	43.4	53.8	54.2	47.1	36.4	40.7	41.7
16	81.5	68.2	74.4	74.8	71.8	55.3	63.6	63.5	62.1	40.9	50.6	51.5	46.6	29.0	35.4	37.8
17	77.8	60.8	70.0	69.3	71.0	57.8	63.4	64.4	60.0	38.0	49.7	49.0	52.3	30.2	39.8	41.2
18	79.0	61.5	70.7	70.2	70.3	54.0	62.4	62.1	59.1	39.5	49.1	49.3	49.1	33.0	39.5	41.0
19	79.9	66.7	73.8	73.3	69.3	53.2	61.4	61.2	63.3	40.4	52.1	51.8	49.3	30.7	39.6	40.0
20	80.1	68.7	74.9	74.4	63.8	51.0	58.7	57.4	57.0	41.8	49.8	49.4	47.5	30.2	37.7	38.8
21	83.1	66.2	75.7	74.6	61.9	52.7	57.0	57.3	61.0	43.0	50.8	52.0	45.7	26.0	35.8	35.8
22	82.9	69.5	77.0	76.2	65.6	51.9	59.8	58.7	60.4	37.6	50.6	49.0	55.1	24.7	38.5	39.9
23	88.9	72.4	79.4	80.6	64.4	57.5	60.9	60.9	48.5	41.3	45.5	44.9	45.3	32.0	39.2	38.6
24	74.1	62.5	67.0	68.3	69.2	57.0	62.2	63.1	57.8	34.4	46.7	46.1	39.1	25.1	32.9	32.1
25	74.0	59.2	67.2	66.6	70.0	52.4	61.3	61.2	57.2	37.4	46.8	47.3	45.3	22.3	34.4	33.8
26	72.0	63.8	68.9	67.9	70.2	51.3	61.3	60.7	61.1	36.0	48.6	48.5	47.6	22.8	33.6	35.2
27	73.0	60.5	66.3	66.7	69.8	48.8	61.3	59.3	60.9	40.6	48.6	50.7	48.3	24.0	35.8	36.1
28	76.0	53.9	66.4	64.9	67.4	52.9	60.6	60.1	53.9	41.5	46.8	47.7	42.5	25.7	33.4	34.1
29	74.0	59.1	66.2	66.5	70.8	54.4	61.7	62.6	52.9	38.0	44.5	45.4	47.0	22.3	34.2	34.6
30	71.7	53.0	62.6	62.3	68.5	51.2	59.2	59.8	57.3	30.8	44.0	44.0	47.2	32.3	38.3	39.7
31	...	...	...	...	59.8	47.2	52.7	53.5	...	...	...	...	44.1	25.6	33.4	34.8

TABLE E. SHOWING THERMOMETRIC RANGE FOR EVERY DAY IN THE YEAR.

Day	January	February	March	April	May	June	July	August	September	October	November	December
1	17.5	10.5	15.7	20.4	17.7	2.7	3.0	15.7	11.6	13.2	18.6	23.7
2	19.4	24.1	1.4	16.6	20.5	8.2	13.6	13.8	12.5	7.7	16.6	23.4
3	24.4	29.7	13.0	10.7	19.6	10.1	4.0	10.6	14.3	9.7	23.2	17.9
4	16.3	11.7	12.7	13.4	9.6	15.7	12.4	14.7	17.2	15.9	21.4	22.4
5	21.0	12.0	12.9	19.5	20.0	20.1	3.5	13.9	7.2	19.0	22.5	17.5
6	17.7	12.3	18.4	10.6	13.7	19.3	12.8	13.4	8.0	7.5	5.6	17.0
7	21.3	16.0	22.0	20.8	16.3	10.4	11.0	11.7	13.9	12.2	17.0	22.7
8	21.5	6.9	4.2	20.8	22.0	17.8	14.8	8.1	18.6	13.7	23.8	19.9
9	17.0	4.4	16.2	17.6	22.2	12.5	11.0	6.3	11.8	19.7	28.1	24.1
10	19.0	21.3	22.6	23.2	4.4	14.5	11.6	11.4	14.2	18.9	23.9	22.9
11	22.2	8.9	13.5	15.7	23.2	5.3	13.3	14.4	13.4	19.0	22.9	25.2
12	15.7	8.0	16.4	10.1	18.0	10.5	10.7	6.7	14.1	4.7	9.0	20.5
13	20.2	14.8	21.0	6.0	19.1	12.9	11.1	17.3	17.6	7.7	5.3	19.1
14	15.7	19.7	21.4	14.4	10.0	16.7	9.8	10.7	13.3	19.7	16.9	23.1
15	17.9	28.3	27.2	14.3	15.5	16.7	10.6	17.7	13.1	17.3	21.6	10.7
16	13.8	28.1	19.8	3.8	10.8	10.9	10.7	8.8	13.3	16.5	21.2	17.6
17	24.0	4.2	20.2	5.9	18.7	17.5	17.2	10.2	17.0	13.2	22.0	22.1
18	16.5	11.0	12.0	13.3	24.0	5.5	17.0	13.0	17.5	16.3	19.6	16.1
19	11.8	3.8	13.8	18.3	12.8	7.2	16.0	9.7	13.2	16.1	22.9	18.6
20	14.8	17.9	26.7	18.1	19.4	7.2	14.3	14.5	11.4	12.8	15.2	17.3
21	7.7	7.0	19.2	23.0	18.2	7.6	6.9	13.0	16.9	9.2	18.0	19.7
22	16.9	8.4	16.8	14.5	7.8	11.6	12.0	18.4	13.4	13.7	22.8	30.4
23	18.5	13.0	12.3	11.8	15.5	12.7	15.7	13.1	16.5	6.9	7.2	13.3
24	14.2	17.5	10.0	16.2	15.5	8.0	12.7	18.7	11.6	12.2	23.4	14.0
25	19.0	13.1	26.5	11.0	20.0	8.3	6.3	11.9	14.8	17.6	19.8	23.0
26	22.0	24.8	25.3	20.9	26.6	15.0	8.4	12.3	8.2	18.9	25.1	21.8
27	19.0	12.5	23.5	14.5	18.5	15.0	10.7	9.2	12.5	21.0	20.3	21.3
28	19.1	19.0	13.6	13.3	14.6	10.0	5.1	11.7	22.1	14.5	12.4	16.8
29	19.2	7.1	17.0	8.0	11.3	13.7	10.7	12.3	14.9	16.1	14.9	21.7
30	15.2	.....	18.6	6.9	19.0	10.6	8.7	13.9	18.7	17.3	26.5	14.9
31	15.0	.....	8.6	.....	6.5	.....	11.4	8.0	.....	12.6	.....	18.5

TABLE F. SHOWING MONTHLY MEANS, MAXIMA MINIMA AND RANGE OF THE THERMOMETER.

	Jan.	Feb.	March	April	May	June	July	August	Sept.	Octob.	Novem.	Decem.	Year
Means from Sd. Ther.	36.3	41.6	46.6	53.7	64.2	68.0	76.1	78.5	72.2	61.6	50.1	38.8	57.3
Means from Max. & Min.	36.5	41.6	46.5	53.4	63.3	67.7	75.5	77.8	72.0	61.4	50.4	39.4	57.1
Max.	52.9	64.0	68.0	73.5	82.0	81.0	88.7	90.5	88.9	76.0	68.2	57.9	90.5
Min.	23.0	26.4	28.0	35.0	42.5	56.3	64.4	65.0	53.0	47.2	30.8	22.3	22.3
Max. Range	24.4	29.7	27.2	23.2	26.6	20.1	17.2	18.7	22.1	21.0	28.1	30.4	30.4
Min. Range	7.7	3.8	1.4	3.8	4.4	2.7	3.0	6.3	7.2	4.7	5.3	10.7	1.4

Chart No. 3

Showing the readings of standard thermometer during the year 2540 (1880)

第三圖

紀元二千五百四十年 明治十年 寒暖計昇降

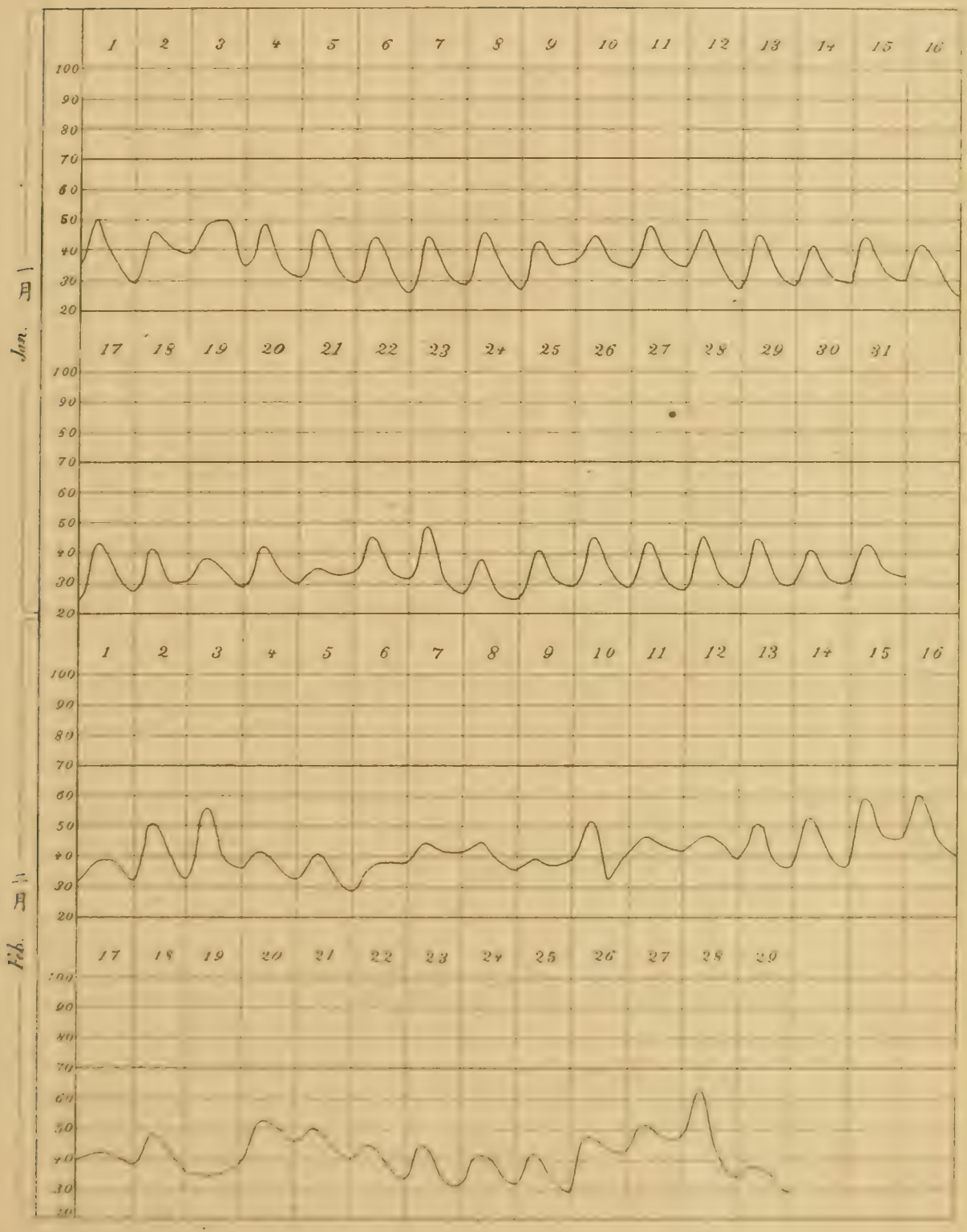


Chart No. 3

Showing the readings of standard thermometer during the year 2540 (1880)

第三圖

紀元二千五百四十年明治十三年寒暖計昇降ノ圖

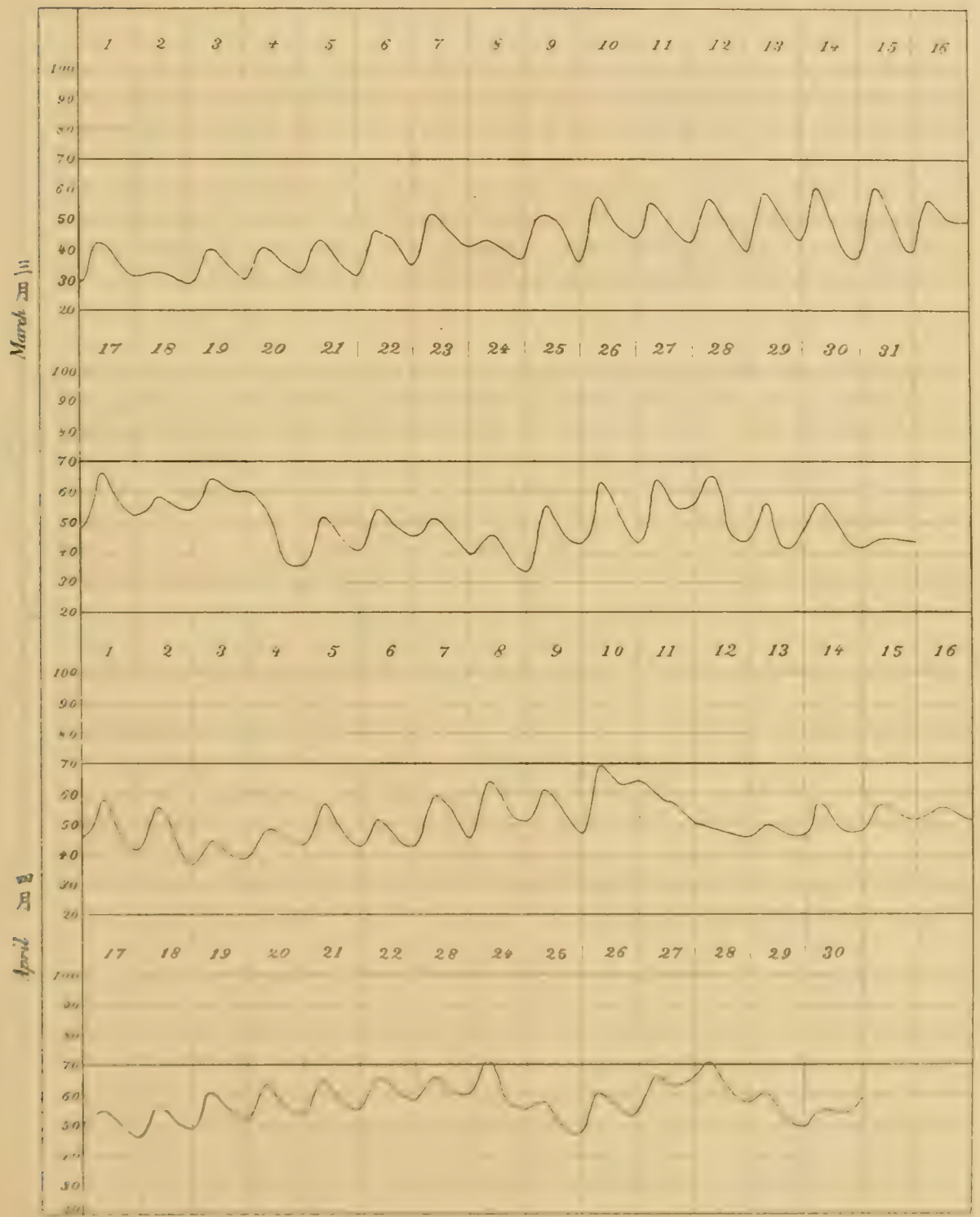


Chart No. 3

Showing the readings of standard thermometer during the year 2540 (1880)

第三圖

紀元二千五百四十年明治十三年寒暖計昇降ノ圖

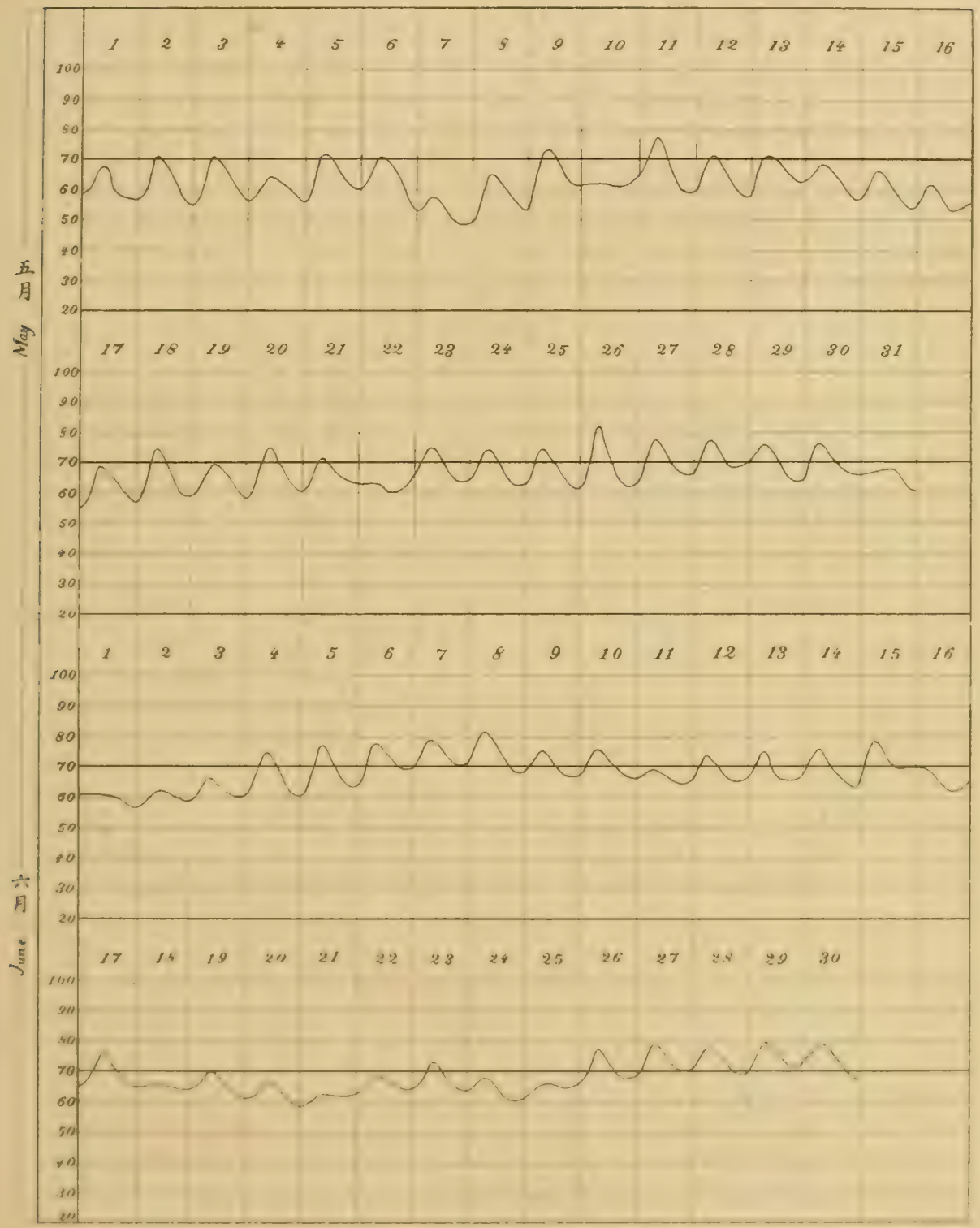


Chart No. 3

Showing the readings of standard Thermometer during the year 2540 (1880)

第三圖

紀元二千五百四十年明治十三年寒暖計昇降ノ圖

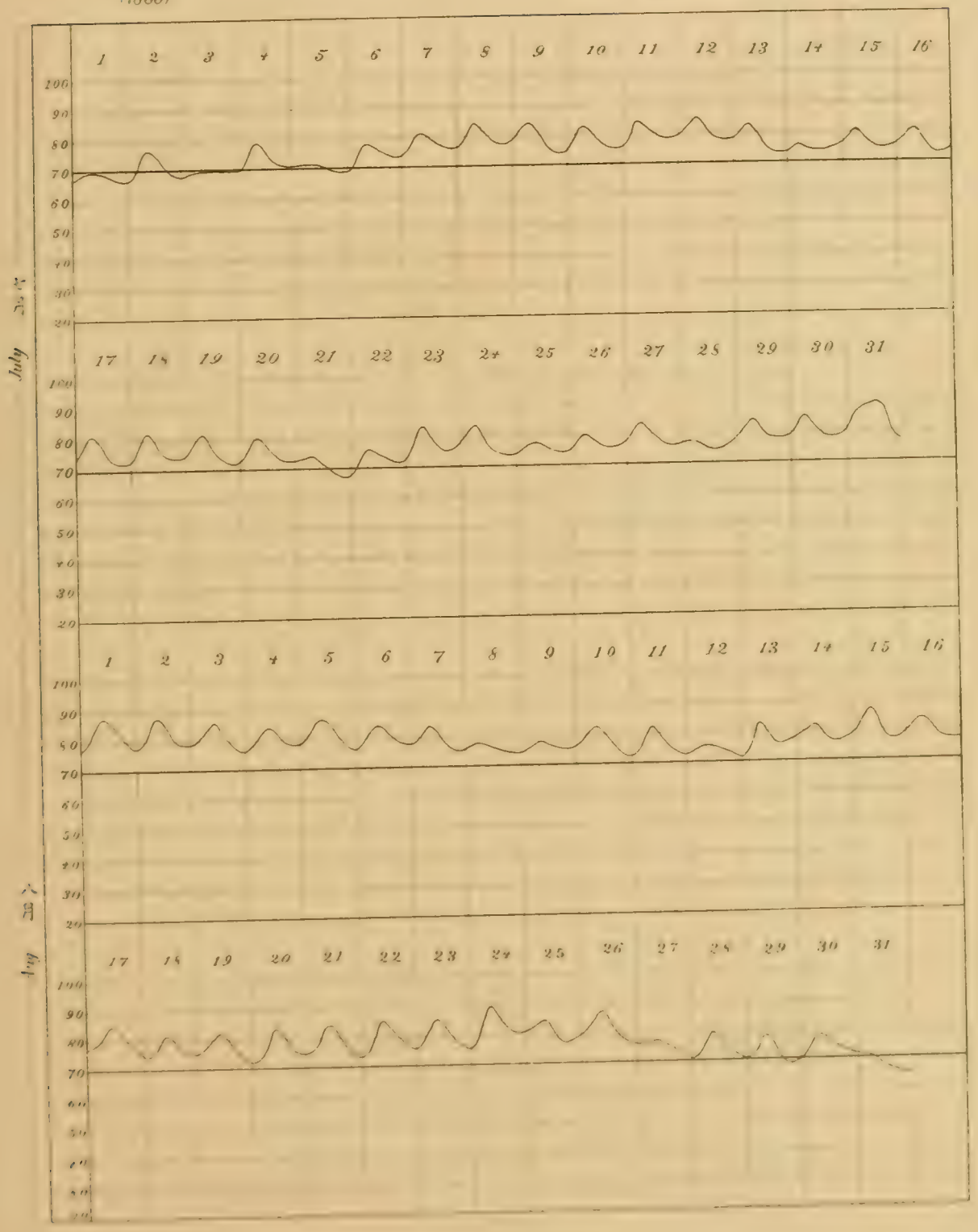
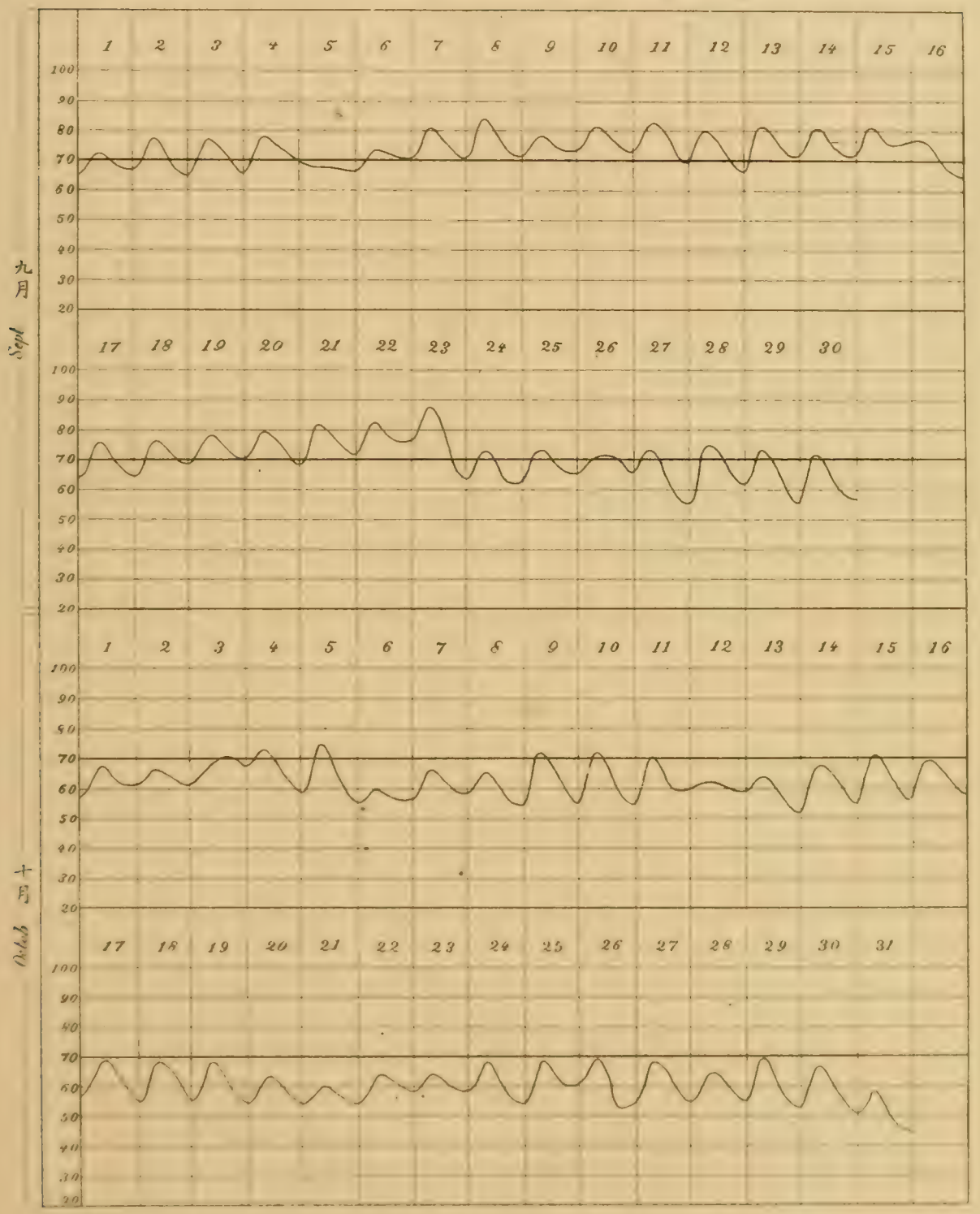


Chart No. 3

Showing the readings of standard thermometer during the year 2540 (1880)

第三圖

紀元二千五百四十年明治十年三年寒暖計昇降ノ備



第三圖

紀元二千五百四十年（明治十三年）寒暖計昇降ノ圖

Chart N°3

Showing the readings of standard thermometer during the year 2540 (1880)

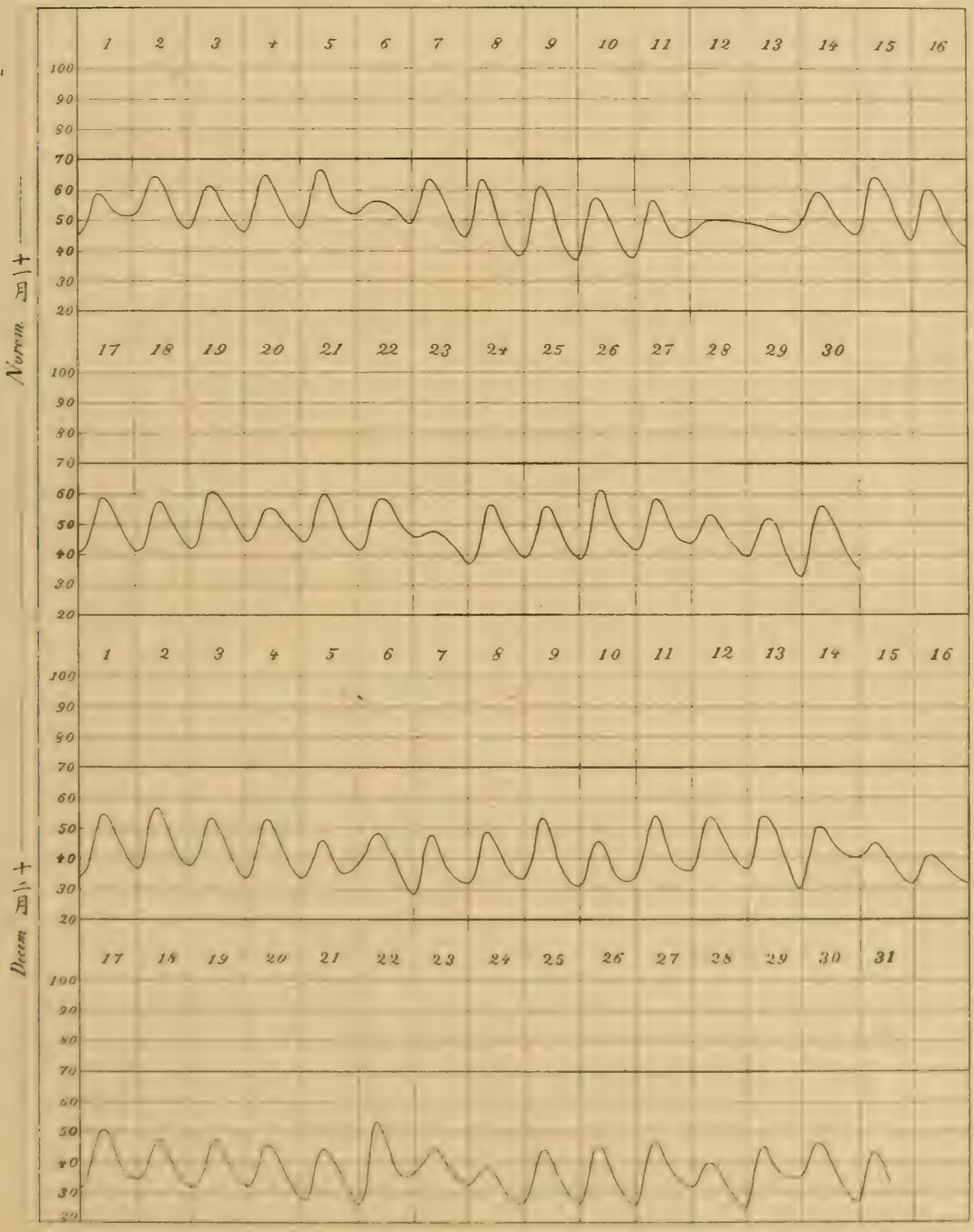


Chart N°4

Showing 1st monthly means of standand thermometer,
2nd max. min. and range for each month.
3rd max. and min. daily range for each month

第四圖

第一　紀元二千五百四十年（明治十三年）各月中寒暖計平均度、

第二　同年各日中寒暖計最高最低並昇降限界、

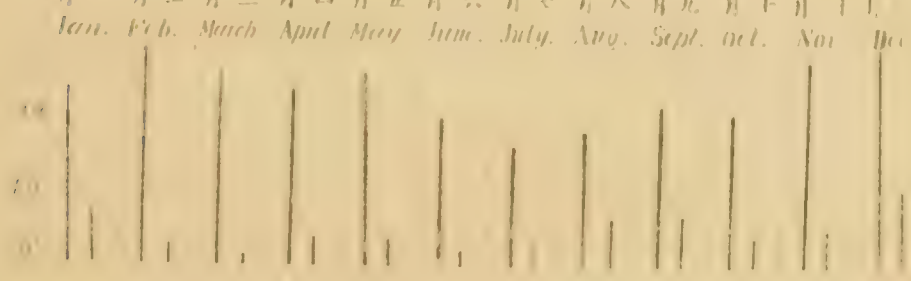
第三　同年各月中一日ノ中ニテ最大最小ノ昇降ノ差、

但一月中最大最小ノ差ハ二日ニ顯ハル

一月 Jan. 二月 Feb. 三月 March 四月 April 五月 May 六月 June 七月 July 八月 Aug. 九月 Sept. 十月 Oct. 十一月 Nov. 十二月 Dec.

一月 Jan. 二月 Feb. 三月 March 四月 April 五月 May 六月 June 七月 July. 八月 Aug. 九月 Sept. 十月 Oct. 十一月 Nov. 十二月 Dec.

一月 Jan. 二月 Feb. 三月 March 四月 April 五月 May 六月 June 七月 July. 八月 Aug. 九月 Sept. 十月 Oct. 十一月 Nov. 十二月 Dec.



THE WIND.

Observations upon the velocity and direction of the wind have been continued by means of the anemograph and Robinson's Anemometer referred to in the report for last year. The anemometer was blown from its place and considerably injured in the typhoon of October 4th. Fortunately it was possible to repair it but for a few weeks subsequent to that time the results are entirely based on the records of the anemograph. Experience seems to have demonstrated that the ordinary lighter forms of anemometer have not sufficient strength to resist the high winds to which they are so frequently exposed at this point. It would be extremely desirable if their construction could be modified in some way so that their power of resistance might be increased without at the same time diminishing their sensibility.

Table G. gives the actual number of miles of movement of the atmosphere, *since the last observation,* at each of the three observations for every day in the year, with totals. From this it will be seen that the total movement of the air during the year in all directions was 53279.5 miles, being an average of 145.5 miles for each day or a trifle more than 6 miles per hour. Compared with the total movement for the previous year, this is an increase of nearly four thousand miles or about eight percent of the whole. During the Months of March, May, July and September of 1880 the movement of the atmosphere was less than for the corresponding months of 1879, but during the remainder of the year it was considerably greater. Table H gives the direction of the wind at every observation made during the year. When there is no perceptible motion of the air at the time of making the observation, the word "calm" is inserted.

Table I exhibits the total movement of the atmosphere for every day in the year with the prevailing direction of the wind during the day and the maximum and minimum movements for each month. As stated in the previous report it is very difficult, in many instances, to determine the *prevailing direction* correctly, hence it is highly probable that this table will, in certain cases, appear inconsistant with others.

The maximum movement of the air in a single day occurred on March 20th and amounted to 565.9 miles or an average of about 23.6 miles per hour for the whole day. This is less than the maximum movement for 1879 which amounted to 597.5 miles on December 26th. Although on March 20 the average velocity during the whole day was higher than on any other day of the year, the real maximum velocity of the wind was by no means reached on that day. This occurred on the night of October 3 and 4 at which time the wind reached such a degree of violence as to entitle it to a place among the most violent "typhoons" which have visited this region for several years. Some special observations of velocity of the wind and the barometric height were made during the storm and they are referred to in another place, diagrams of the most important changes

being given. Then were three days in the year in each of which the total amount of wind exceeded four hundred miles. They were February 28, March 20 and October 4. If the barometric curves be examined at these dates it will be seen, of course, that these high winds were preceded or accompanied by a rapid and considerable fall in the barometer, the minimum barometric height for the year occurring at 7 a. m. on March 20, the day on which the maximum number of miles of wind is recorded. The minimum amount of wind recorded on any single day in the year was 34.7 miles on May 19 and the smallest amount for any month was 3288.9 miles in the month of September.

Tables K, L, and M, exhibit the winds classified as to direction and velocity. Table L shows the classification of the winds exceeding twenty miles per hour in velocity, according to direction, for all the months of the year. From this it will be seen that on 83 occasions the wind was recorded as reaching a velocity of twenty miles or more. By comparison with the corresponding tables for the year 1879 it appears that high winds were more frequent during this year than the last, in about the ratio of two to one, the number recorded for last year being 40. A very similar distribution will be observed, however, as to direction and also as to time. The same marked excess of these winds from the North and Northwest is shown in both tables. During the year 1880, out of a total of 83 high winds, 61 are recorded from the North and Northwest; in 1879 the number was 30 out of a total of 40, the ratio being almost exactly the same. Concerning these two directions, however, the proportion for 1879 is reversed in 1880, by far the greater number being recorded from the North. An examination of table M, which shows the classification of the total miles of wind as to time and direction, proves that the largest part of the atmospheric movement is from the same direction. Out of a total of 53279 miles of wind during the year, 28791 miles, or something more than one half came from the North and Northwest. In 1879 the proportion was slightly less than one half. Both of these tables, in connection with table K, show the excess, in both velocity and frequency, of winds from the North and Northwest.

A clearer conception of these facts, however, can be obtained by an examination of charts numbered from 5 to 10 which have been constructed to represent the distribution of winds as to direction and time, according to the method described in the last report. Some peculiarities of these diagrams, to which attention was called in the last report, are again repeated in the curves for 1880. In chart number 5, which exhibits the prevailing directions for the months of the year, there is the same appearance of a shifting of the wind from the North to the South through the East during the months of May, June, and July, and the same sudden change from South winds in August to North winds in September. Indeed, if the general chart for the Year, number 7, be compared with the corresponding chart for 1879, it will be seen to resemble it very closely, about the only difference being due to the fact that winds from the North exceeded in number those from the Northwest to a

greater degree in 1880 than in 1879. In fact a comparison of all of the wind charts of 1880 with those of 1879 indicates a considerable degree of permanency in the annual atmospheric movements. To facilitate this comparison, a series of charts, numbered 5*a* to 10*a*, have been prepared, showing results corresponding to the foregoing, their construction having been based on the mean of the results for 1879 and 1880. The method of constructing the first diagram in chart number 10 was explained in the last report. It shows the general course of the wind during the year 1880 and it indicates a resultant movement of the atmosphere of 18000 miles from a direction North by about 4° East. Number 10a shows a similar construction for the mean results of 1879 and 1880. It indicates a mean annual movement of 14000 miles from a point North by 8° West. The second diagram in chart number 10 consists of a curve showing the number of miles of wind for each month of the year. It agrees very well in its general features, with the corresponding curve for 1879 and in the second diagram of chart number 10a the mean curve for the two years will be found. This exhibits a great maximum in March and two other maxima, one in July and the other in October.

If these mean curves be continued from year to year as observations accumulate, they will, in time, approximate very closely to a stability in form, and it does not seem to be assuming too much to affirm, upon the evidence of but two years' observations, that this form will not differ greatly from that in which they now appear.

THE TYPHOON OF OCTOBER 3 AND 4.

On the night of October 3 and 4 occurred a wind storm of extraordinary violence, although, fortunately, of short duration. Indeed, so rapid were the barometrical changes, that, coming as it did between two of the regular observations, it may be said to have hardly left an impression upon the regular series. Although without doubt the barometer reached the lowest point for the year at that time, in the regular series the minimum is credited to March 20 as is previously stated. Fortunately Mr. Nobutani, recognizing the unusual violence of the storm, began making hourly observations of the barometer at 1 o'clock a. m., afterwards increasing their frequency to every half hour, and continued them until the following morning when the storm had entirely subsided. The anemograph furnishes a continuous record of the velocity of the wind and we are thus able to trace, with tolerable completeness, the most important elements of the phenomenon. The storm was by no means local as it is known to have caused much damage along a considerable extent of the coast, and to have brought about much disaster to shipping in the adjoining seas. In order to undertake anything like a complete discussion of the phenomenon, it would be necessary to collect from numerous and widely distributed sources, all of the facts

possible concerning its rise and progress. This task, which is by no means an easy one, has been undertaken by others who have unusual facilities for accomplishing it, and it will be desirable to confine this brief account to the results of the records made in the observatory, and their description may be borrowed, with slight modifications, from a discussion of the principal meteorological features of the storm, given by the writer in the columns of the *Japan Weekly Mail*, soon after its occurrence.

Although it can hardly be said that this storm gave any marked indications of its immediate approach, yet it is important to observe that there was a steady fall in the barometer from the previous Thursday—September 30th—up to the time of maximum violence of the wind. Chart number 10c exhibits the barometric curve during the most interesting period; *i. e.* from 7 o'clock a. m. on the 3rd of October, to 2 o'clock p. m. of the 4th. Previous to one o'clock on the morning of the 4th but three observations are recorded; at 7 a. m., at 2 p. m., and at 10 p. m. These indicate a steady decline in the barometer and it is not likely that any extraordinary fluctuations occurred during this time. After one o'clock a. m., the observations were made hourly, and during a considerable portion of the time they were half-hourly. It will be seen, however, that a very important portion of the curve, from 10 o'clock p. m. to 1 o'clock a. m., is doubtful and it is not at all unlikely that, had intermediate observations been recorded, the fall of the barometer would have appeared much more sudden than it does. The minimum observed height was 28.735 inches at 2 o'clock a. m. At 3 o'clock the height was only a trifle greater than this and, from the nature of the curve before and after the interval from 2 o'clock to 3 o'clock as well as from the velocity of the wind, it seems highly probable that between these hours a lower point than any observed was reached. The curve is constructed to show the actual vertical movement of the mercurial column. From the minimum it rose rapidly until 6 o'clock a. m. at which hour the height was 29.386 inches, and from that hour the rise continued with less rapidity but with great steadiness, until the night of the following Wednesday, when the reading was 30.378 inches. Thus the range of the barometer in three days was 1.643 inches. This is more than two-tenths of an inch greater than the range for the whole of the last year and nearly three-tenths of an inch greater than the range from the regular series of observations for this year. At no time during last year did the barometer reach so low a point as 29 inches, and the mean height for the year was 29.952 inches.

Chart number 10*d* shows the velocity of the wind at different hours extending over the same interval of time. These velocities are computed from a continuous record made by the anemograph consisting of a Robinson's anemometer with Beckley's registering apparatus attached. From this curve it will be seen that, so far as the wind is concerned, up to about 11 o'clock p.m. there were no indications of the coming storm. At that time a breeze sprang up, which continued at less than twenty miles per hour until about 1 o'clock a.m. when it

suddenly increased in velocity, and at 2 a.m. the record shows a speed of sixty miles per hour. Unfortunately shortly after 2 o'clock, the clock-work which keeps the registering portion of the apparatus in motion was stopped, the motion of the pendulum being undoubtedly arrested by a sudden blast of great violence. This stoppage was not discovered until 3 o'clock a.m., so that between these hours the record is lost. At 3 o'clock the instrument was put in motion again and for about fifteen or twenty minutes after that hour, the record shows the extraordinary velocity of ninety-five miles per hour. From this time the violence diminished rapidly, a velocity of fifty miles per hour being registered at 4 a.m., and at 5 a.m. it had fallen to less than twenty miles per hour. Twice afterwards as will be seen by the chart, the speed rose to about twenty-five miles per hour, after which it rapidly declined.

Owing to the interruption in the continuity of these records, it is impossible to affirm that the maximum velocity of the wind was recorded. In fact there are reasons for believing that the storm reached its greatest violence somewhat before 3 o'clock.

It seems quite certain then, that at times during the storm the velocity of the wind exceeded one hundred miles per hour; and especially must this have been the case during some of the most violent blasts which were generally of too short duration to show with their full effect upon the register made. The fact that the pendulum of the anemograph was stopped between 2 o'clock and 3 o'clock by one of these blasts, and that after 3 o'clock its motion was not interfered with, would indicate that more violent disturbances took place before than after that hour. A smaller anemometer of Robinson's model was torn from its fastenings between 2 o'clock and 3 o'clock, and so completely demolished that no record even of the work which it had already done could be obtained. This is much to be regretted, as otherwise a means of verifying the extraordinary velocity registered by the anemograph would have existed. Concerning the latter it should be said that, regarding the smaller anemometer as a standard, it has been found upon examination to somewhat over-estimate the velocity of very high winds, and to under-estimate those of low speed. At the same time it cannot be positively stated which of the two instruments was in error.

A continuous record of the direction of the wind is kept. Upon examining this it is found that during the whole of the period considered, the direction varied between North and West. Up to 1 o'clock a. m. of the 4th the wind was steadily from the North-north-west. From that hour until 5 o'clock a. m. its fluctuations were confined between North-west and West. A decided change in direction seems to have taken place between the hours of 2 o'clock and 3 o'clock.

The early part of the storm was accompanied by an unusually heavy fall of rain. The violence of the wind prevented the reading of the rain-gauges during the night, but when emptied at 7 a.m. they showed a total of 4.66 inches, nearly all of which must have fallen during—at most—two or three hours.

It may be interesting to make some comparisons between the violence of

this storm, and that which was undoubtedly the immediate cause of the destruction of the Tay Bridge, on the evening of the 28th December, 1879. Unfortunately it does not appear that any very exact or reliable obsersvations of the velocity of the wind on that occasion were made; but an approximate measure of it may be obtained from the testimony of several of the witnesses, who were men of considerable experience in the observation and estimation of high winds. The following selections from the *Times* report of the Board of Trade inquiry, are of interest in this connection. Captain Scott, R. N.—who was superintendent of a training-ship stationed in the Tay, testifies that his barometer fell from 29.60 inches at noon to 29.00 inches at 7 o'clock—that being the lowest point reached. Also that in the Navy, storms were described by numbers from 1 to 12, 12 being the maximum. Upon that scale he would describe this storm in the Tay as from 10 to 11. He had on rare occasions in China and the West Indies rated storms as high as 12.

Admiral William Heriot Maitland Dougal, who had resided at the mouth of the Tay continuously for twenty nine years, stated that his barometer fell from 29.40 inches to 28.80 inches. The difference between these and the previous barometric heights, is easily explained by the fact that his house was at an altitude of 200 feet above the level of the sea. He declared that the gale was like a typhoon in violence, and that in all the time during which he had lived on the Tay, he had never experienced a gale of equal severity. In his opinion the velocity of the wind was from seventy-five to seventy-eight miles per hour, and that during the lulls it would fall to something like thirty.

Charles Clark, who was an amateur observer, gave evidence that 29.00 inches was the minimum point reached, and that he had marked the storm 4 on a scale of 6; and that he had never yet recorded 5 or 6.

Other witnesses testified in about the same way, all agreeing reasonably well as to barometric depression and probable velocity.

On comparing these statements with those already made concerning the recent typhoon here in Japan, it will be seen that both in barometric range and in wind velocity, the recent storm considerably exceeded that which was the occasion of the Tay Bridge disaster. The barometric change was not only greater, but more sudden in the former than in the latter. Concerning the direct measurement of the pressure of the wind in pounds per square foot, it must be said that the instruments for doing this are, at present, to a great extent crude and unreliable. It is generally assumed that the pressure is proportional to the square of the velocity. Upon a scale adopted by the Smithsonian Institution and by the United States Signal Service, the velocity of twenty-five miles per hour corresponds to a pressure of 3 lbs. per square foot. Assuming the correctness of this and also of the law given above, the pressure per square foot in the Tay storm must have been nearly 30 lbs. and in the recent typhoon here it must have been nearly 50 lbs. It was shown in the tests made upon the material of the Tay Bridge, that it might have been expected to give way under a wind pressure

considerably less than 40 lbs. The French and many English engineers have adopted 55 lbs. per square foot as a standard, and about the same number is used in America, but it seems doubtful if even that furnishes a sufficient "factor of safety."

In conclusion, it may safely be said, especially in view of the damage done to buildings, shipping, etc., that this was one of the most violent storms experienced here for many years. From facts already known concerning other points along the coast of Japan, it would seem that, had an efficient system of observations, telegrams, and signals existed, timely warning might have been given of its approach and, possibly, much property and many lives saved.

TABLE G. SHOWING MILES OF WIND RECORDED AT EACH OBSERVATION IN THE YEAR.

Day.	January			February			March			April		
	7	2	10	7	2	10	7	2	10	7	2	10
1	90.6	28.6	31.6	38.2	48.5	32.3	55.1	63.5	43.8	28.5	95.4	140.6
2	27.2	22.3	20.3	33.9	37.9	25.0	84.5	75.5	63.7	93.6	37.8	78.4
3	84.5	56.8	24.9	29.4	46.8	93.9	73.4	46.9	34.1	107.3	115.1	126.1
4	11.9	23.1	24.3	57.5	68.8	107.7	42.3	53.5	55.6	127.4	63.3	85.4
5	21.6	22.3	31.1	166.5	133.2	39.6	52.9	80.2	52.7	111.8	113.4	53.1
6	39.4	24.0	73.2	65.4	67.0	59.6	30.7	37.2	32.6	23.5	56.3	44.8
7	14.3	38.5	47.7	55.4	43.6	35.2	47.2	34.6	29.8	31.1	39.1	43.3
8	42.3	23.7	15.8	21.7	27.0	72.4	22.3	39.6	59.9	25.2	34.4	45.2
9	24.7	12.9	15.2	92.2	71.6	64.9	20.4	28.5	29.1	24.2	38.6	73.0
10	31.2	116.0	85.7	109.7	95.8	36.4	23.4	40.0	56.4	29.4	89.7	121.9
11	71.7	60.1	51.7	25.5	42.4	49.9	81.3	53.7	71.4	140.1	130.4	55.0
12	85.6	50.2	50.3	78.8	56.8	11.9	36.6	45.8	32.7	47.8	49.3	42.4
13	17.1	55.2	76.8	123.5	106.7	112.4	39.7	32.6	59.1	56.8	61.7	40.0
14	43.2	9.9	21.5	129.2	43.4	35.8	30.8	28.0	105.0	53.4	64.0	48.4
15	29.6	60.9	87.3	21.8	35.0	64.6	61.5	21.6	27.9	35.9	36.6	49.3
16	89.3	101.8	74.3	90.0	80.5	136.3	31.1	26.3	25.8	60.8	44.6	24.5
17	19.0	51.9	79.4	77.6	47.2	51.0	34.0	41.1	73.0	117.3	44.0	42.6
18	72.5	88.4	75.4	56.2	48.5	36.2	55.9	69.3	24.6	63.8	68.7	53.9
19	35.0	75.6	18.0	50.0	58.2	99.2	14.9	53 7	74.3	14.6	40.1	64.6
20	44.0	30.6	14.0	169.1	126.2	26.5	169.1	181.8	215.0	23.0	45.3	60.2
21	33.4	45.1	59.5	46.8	33.8	48.4	85.4	75.2	34.6	29.0	50.1	49.7
22	57.6	150.8	124 3	92.6	72.1	79.7	39.2	33.9	17.3	14.3	35.6	29.0
23	51.9	51.2	105.7	67.3	109.8	86.0	20.5	28.5	114.0	7.8	36.7	121.4
24	77.1	52.8	22.1	23.7	40.6	29.4	184.4	180.6	129.1	56.8	26.8	67.2
25	31.1	32.8	22.6	88.0	87.1	40.6	52.4	53.3	44.8	54.7	144.5	191.4
26	24.8	24.4	99.5	48.8	65.0	19.4	33.5	36.4	46.5	56.2	51.9	88.0
27	103.9	52.0	22.1	32.2	19.9	27.6	30.6	50.5	82.2	37.2	61.8	124.7
28	38.5	49.1	18.9	155.3	125.3	156.6	73.6	68.5	109.2	122.3	74.7	36.0
29	46.4	41.7	11.5	115.6	70.7	64.3	54.7	35.7	92.8	34.1	36.7	19.1
30	101.4	147.2	90.4	.....	.....	.....	74.1	137.1	95.4	29.7	61.2	79.3
31	87.7	32.8	15.7	.....	.....	.....	61.2	48.7	81.4	.....	.....	.....
Sums	1547.9	1632.7	1510.8	2161.9	1909.4	1742.8	1716.7	1801.8	2013.8	1657.6	1847.8	2098.5
Total	4691.4			5814.1			5532.3			5603.9		

TABLE G. SHOWING MILES OF WIND RECORDED AT EACH OBSERVATION IN THE YEAR.

Day.	May			June			July			August		
	7	2	10	7	2	10	7	2	10	7	2	10
1	29.5	36.9	32.9	57.6	45.9	48.8	46.8	[illegible]	[illegible]	[illegible]	19.1	[illegible]
2	47.2	39.1	45.9	40.4	20.4	8.6	69.0	[illegible]	[illegible]	12.5	[illegible]	[illegible]
3	11.1	31.1	80.2	12.7	23.6	38.0	20.9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4	22.2	22.0	27.3	36.9	30.9	34.1	10.3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5	9.6	34.8	79.4	13.1	26.4	40.2	40.8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6	19.7	61.8	105.2	12.3	35.5	47.9	7.5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7	128.4	72.6	44.6	86.6	114.6	98.7	18.2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
8	22.0	47.6	54.6	32.6	56.8	70.1	10.7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9	16.8	23.4	47.0	24.8	27.1	43.3	12.6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
13	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
14	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
16	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
17	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
18	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
19	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
20	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
21	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
22	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
23	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
24	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
25	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
26	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
27	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
28	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
29	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
30	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
31	16.0	37.1	58.7	.....	.....	.....	53.7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Sums	901.5	1104.4	1474.6	1044.3	1123.1	1449.1	1018.3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Total	3566.5			3616.5			[illegible]			[illegible]		

TABLE G. SHOWING MILES OF WIND RECORDED AT EACH OBSERVATION IN THE YEAR.

Day.	September			October			November			December		
	7	2	10	7	2	10	7	2	10	7	2	10
1	80.1	72.6	49.5	58.2	43.3	50.0	48.0	38.5	23.2	31.3	17.9	21.8
2	67.9	67.2	55.0	65.4	53.3	32.9	80.5	80.9	30.0	34.0	65.2	54.4
3	51.6	44.0	30.0	82.1	44.5	13.3	26.0	13.5	14.0	33.9	34.3	34.6
4	27.2	23.9	20.5	273.0	124.0	30.5	46.5	34.8	19.0	20.1	61.6	84.5
5	12.7	26.9	25.4	3.0	15.0	52.0	18.8	22.0	22.0	47.9	81.5	78.4
6	26.9	15.0	15.2	22.0	45.5	24.0	31.5	14.0	35.5	105.8	133.4	76.4
7	15.5	15.2	20.8	51.0	70.0	42.0	47.0	40.8	26.5	21.2	19.8	18.1
8	20.8	30.9	21.8	5.0	54.0	60.0	24.0	84.5	66.0	41.5	26.1	20.4
9	23.3	45.0	61.1	43.0	26.5	15.5	17.0	52.0	32.0	36.4	100.8	60.0
10	17.0	46.5	28.7	38.5	57.5	33.0	37.0	38.5	55.5	44.3	56.1	63.0
11	14.3	23.0	56.7	20.0	32.5	23.0	47.0	48.7	34.0	45.2	32.8	77.6
12	45.6	28.9	27.3	19.5	55.0	46.0	77.8	67.8	45.7	39.1	116.8	104.1
13	9.1	27.3	37.5	16.5	34.7	23.0	66.8	44.5	44.3	29.5	34.9	35.8
14	17.7	48.7	73.3	26.0	37.5	22.5	140.8	98.2	98.0	32.3	22.5	36.5
15	37.0	57.7	91.0	10.0	18.5	7.5	96.8	107.0	125.5	55.5	57.4	31.9
16	85.9	78.2	38.2	24.0	16.0	3.0	42.2	35.1	20.2	46.3	98.1	107.8
17	29.4	40.4	35.0	23.0	50.5	26.5	33.2	45.0	19.1	36.7	43.0	51.9
18	22.0	26.4	39.0	63.5	57.2	31.8	43.1	37.4	28.9	71.7	87.5	44.2
19	4.7	15.5	40.5	71.5	60.0	23.7	29.0	38.3	23.7	36.9	72.2	83.0
20	15.5	22.8	26.6	42.0	33.8	15.0	36.4	12.4	20.1	80.2	76.5	69.1
21	10.5	10.3	18.5	59.0	55.0	65.5	36.6	50.3	39.2	49.1	26.2	69.4
22	14.7	19.6	15.2	77.3	73.0	54.5	42.9	36.9	29.6	43.8	84.3	49.3
23	30.5	55.6	84.7	81.0	39.0	73.4	40.5	20.8	13.8	59.3	28.1	38.3
24	102.8	46.7	35.0	85.5	80.8	59.0	25.3	35.2	17.2	57.0	136.0	118.5
25	49.5	48.8	35.7	53.8	37.5	13.7	43.5	34.0	16.3	70.4	41.1	36.5
26	44.7	24.7	6.8	33.9	90.0	103.0	28.0	55.5	122.9	32.8	26.8	19.9
27	43.2	67.9	31.4	51.3	86.0	41.8	99.6	52.4	111.5	45.6	30.4	38.3
28	30.5	27.9	11.4	19.0	25.0	4.5	133.7	93.8	75.7	30.9	128.0	143.0
29	14.3	35.2	35.0	23.5	31.0	10.0	71.6	41.8	19.3	71.3	41.7	51.2
30	38.7	65.4	59.3	24.0	23.8	21.5	30.5	26.0	28.4	115.2	132.3	56.6
31	.....,	.....	.....	140.3	140.0	62.5	.....	.....	.....	27.5	38.4	15.4
Sums	1003.6	1159.2	1126.1	1611.5	1610.1	1084.6	1541.6	1400.6	1257.1	1502.7	1952.7	1789.9
Total	3288.9			4309.5			4199.3			5245.3		

TABLE II. SHOWING DIRECTION OF THE WIND AT EACH OBSERVATION IN THE YEAR.

Day.	January			February			March			April		
	7	2	10	7	2	10	7	2	10	7	2	10
1	N	SE	NW	N	N	N	N	N	N	N	N	N
2	W	N	NW	NW	SE	S	N	N	N	N	E	NE
3	NW	SE	N	W	N	N	N	NE	NE	NW	N	N
4	W	E	NE	N	N	N	N	NE	NE	N	NE	NW
5	W	S	N	N	NE	E	N	N	E	N	NW	E
6	NW	S	NW	N	N	N	N	SE	E	N	N	N
7	NW	N	N	N	N	NE	N	NE	S	NW	S	S
8	NW	S	W	NE	N	N	W	N	NW	SW	SE	S
9	W	S	NW	N	N	N	N	E	E	NW	E	SE
10	NW	N	N	N	N	E	E	S	NW	SE	S	S
11	NW	NW	N	N	N	N	N	SE	SE	SW	NW	N
12	N	NE	NW	N	N	N	N	N	SE	N	NE	N
13	NW	NW	N	N	N	NW	N	S	S	NW	NE	NE
14	N	N	N	N	NE	S	NW	S	N	N	E	E
15	N	N	N	NW	S	S	NW	S	SW	N	NE	N
16	N	N	N	N	N	N	NW	N	NW	N	E	N
17	N	N	N	N	N	N	N	N	E	NE	E	N
18	N	N	N	N	E	E	N	N	E	N	NE	E
19	NW	NE	N	N	N	N	E	SE	S	E	S	S
20	N	E	SE	NW	N	E	W	N	N	W	S	S
21	N	N	N	N	N	N	N	S	S	W	S	S
22	N	N	N	N	N	N	NW	SE	SE	S	S	S
23	NE	N	N	N	N	N	N	NW	N	S	S	SW
24	N	NE	NE	N	NE	N	NW	NW	N	SW	E	N
25	NW	NE	SE	N	NE	E	NW	S	S	NW	NW	NW
26	SE	N	N	N	NE	NE	W	S	S	NW	S	S
27	N	S	S	N	NE	NW	W	S	S	W	S	S
28	W	E	N	NW	NW	N	S	N	NW	SW	N	NE
29	N	SE	S	NE	NE	NE	N	E	NW	N	NE	E
30	N	N	N	.....	.....	.....	NW	N	E	N	N	NW
31	N	N	SE	.....	.....	.....	N	N	W	.....	.....	.....

TABLE H. SHOWING DIRECTION OF THE WIND AT EACH OBSERVATION IN THE YEAR.

Day.	May			June			July			August		
	7	2	10	7	2	10	7	2	10	7	2	10
1	SW	N	N	N	E	E	N	N	E	N	S	NW
2	NW	NE	S	NE	N	Calm	N	N	SE	N	S	S
3	S	S	S	E	E	NE	NE	N	NE	SW	S	S
4	W	S	SE	N	S	Calm	NE	S	S	W	SW	S
5	S	S	S	NW	S	S	S	NE	S	S	SE	SW
6	S	S	S	W	SE	SE	SE	S	S	N	SE	SE
7	N	E	E	E	S	SW	S	NE	NE	NE	SE	E
8	E	S	SW	SW	SW	N	NE	SE	S	SE	SE	E
9	SW	S	SW	N	S	S	SE	SE	W	SE	S	S
10	W	NE	N	NW	S	SW	E	SE	SE	SE	S	Calm
11	N	N	SE	SW	Calm	W	E	Calm	SW	NW	SE	S
12	SE	S	SE	W	E	Calm	S	S	S	Calm	S	NE
13	N	NE	NW	NE	NE	S	E	NE	E	S	S	S
14	E	SE	NW	NE	SE	S	N	NE	N	S	S	S
15	N	SE	S	NW	S	S	NE	NE	E	S	S	S
16	Calm	W	N	S	SE	N	NE	E	SE	S	S	S
17	N	NE	SE	NW	S	SE	Calm	SE	SW	S	SE	N
18	W	S	S	E	N	NE	SW	SE	SW	N	N	E
19	W	W	SW	NE	NE	E	NE	SE	SE	N	NE	NE
20	N	NE	SE	NE	E	N	N	NE	NE	N	N	N
21	SW	S	S	N	NE	NE	N	NE	N	N	NE	E
22	SE	N	NE	N	SE	Calm	N	N	N	N	SE	S
23	NE	S	Calm	N	E	SE	N	SE	S	W	S	SW
24	N	S	S	N	N	NW	SE	SE	SE	NW	SW	SW
25	NE	S	SW	N	NE	N	NE	N	E	SW	S	S
26	W	SE	SE	N	E	E	NE	E	SE	SW	SE	S
27	N	S	S	NW	S	S	E	SE	E	NW	W	S
28	Calm	S	S	N	SE	E	NE	NE	N	W	S	NE
29	S	SE	Calm	N	NE	S	NW	S	S	N	S	N
30	SE	S	S	N	NE	S	S	S	S	N	NE	NE
31	NW	E	SE	.....	.....	.....	SW	NW	S	SE	NE	N

TABLE H. SHOWING DIRECTION OF THE WIND AT EACH OBSERVATION IN THE YEAR.

Day.	September			October			November			December		
	7	2	10	7	2	10	7	2	10	7	2	10
1	N	N	NW	N	NE	N	N	E	NW	NW	NW	W
2	N	NE	N	NW	N	N	N	N	N	NW	N	Calm
3	N	NE	NW	NW	N	SE	E	NW	W	N	N	NW
4	N	S	S	NW	NE	N	NW	E	W	NW	N	NW
5	Calm	NW	Calm	N	N	N	NW	SE	N	NW	N	NW
6	N	N	N	N	NE	N	NW	Calm	N	N	NW	N
7	N	S	NW	N	N	N	W	S	W	N	SE	N
8	W	Calm	SE	N	N	NW	NW	W	N	NW	SE	W
9	E	SE	SE	N	E	SW	S	SW	W	NW	NW	NW
10	SE	S	NW	N	E	E	N	N	N	W	NW	W
11	N	NE	SE	N	NE	E	N	NE	N	SE	NW	E
12	N	NE	E	N	N	N	N	N	N	W	NW	NW
13	Calm	SE	S	N	E	NW	N	NE	N	N	N	NW
14	Calm	S	S	NW	SE	N	N	N	NW	Calm	SE	S
15	NW	S	S	NE	SE	NW	N	N	N	N	N	N
16	S	N	N	NW	N	N	NW	S	W	NW	NW	W
17	N	NE	W	N	N	N	N	NE	W	W	W	NW
18	N	N	SE	N	N	N	N	NE	W	N	N	NW
19	N	SE	SE	N	NE	N	N	S	W	N	N	N
20	N	S	S	N	N	NE	W	N	NW	NW	NW	N
21	NW	S	S	NW	N	N	N	SE	NE	W	N	NW
22	Calm	N	S	N	N	NW	NW	SE	N	SW	S	W
23	SW	S	N	NW	N	NW	E	N	Calm	W	N	NW
24	N	E	N	NW	N	N	N	N	NW	N	N	N
25	N	E	N	N	NE	SE	N	NE	NE	N	SE	SW
26	N	Calm	NW	S	SW	NW	N	W	SW	SW	E	W
27	NE	NE	W	NW	NE	E	SW	SW	NW	NW	S	W
28	N	SE	Calm	N	NE	NW	N	N	N	S	NW	N
29	N	NE	N	NW	S	N	N	S	W	W	S	NW
30	N	NE	N	NW	S	W	N	NW	NW	NW	N	N
31	.....	.....	.....	NW	N	NW	...	.....	.....	N	N	W

TABLE I SHOWING MILES OF WIND AND PREVAILING DIRECTION FOR EVERY DAY IN THE YEAR.

Day.	January		February		March		April	
	Miles	P. D.	Miles	P. D.	Miles	P. D.	Miles	P. D.
1	150.2	N	119.0	N	162.4	N	264.5	NW
2	69.8	NW	96.8	W	223.7	N	209.8	NE
3	166.2	NW	170.1	NW	154.4	NE	348.5	N
4	59.3	N	234.0	N	151.4	NE	276.1	N
5	75.0	NW	339.3	NE	185.8	NE	278.3	W
6	136.6	SW	192.0	N	100.5	E	124.6	N
7	100.5	N	134.2	N	111.6	E	113.5	E
8	81.8	W	121.1	NE	121.8	W	104.8	S
9	52.8	SW	228.7	N	78.0	N	135.8	E
10	232.9	NW	241.9	N	119.8	SE	241.0	S
11	183.5	NW	117.8	N	206.4	NE	325.5	SW
12	186.1	N	147.5	N	115.1	NE	139.5	NE
13	149.1	N	342.6	N	131.4	SE	158.5	NE
14	74.6	N	208.4	NE	163.8	N	165.8	N
15	177.8	N	121.4	S	111.0	E	121.8	N
16	265.4	N	306.8	NW	83.2	N	129.9	N
17	150.3	N	175.8	N	148.1	N	203.9	N
18	236.3	N	140.9	NE	149.8	N	186.4	NE
19	128.6	N	207.4	N	142.9	SE	119.3	SE
20	88.6	NE	321.8	NW	565.9	NW	128.5	S
21	138.0	N	129.0	N	195.2	W	128.8	S
22	332.7	N	244.4	N	90.4	NE	78.9	S
23	208.8	N	263.1	N	163.0	N	165.9	SW
24	152.0	N	93.7	N	494.1	NW	150.8	N
25	86.5	NE	215.7	N	150.5	SW	390.6	NW
26	148.7	N	133.2	N	116.4	S	196.1	S
27	178.0	E	79.7	N	163.3	S	223.7	S
28	106.5	N	437.2	N	251.3	NW	233.0	SW
29	99.6	E	250.6	NE	183.2	N	89.9	NE
30	339.0	N	.....	.....	306.6	NW	170.2	NW
31	136.2	NE	.....	.....	191.3	NW	.....	.....
Max.	339.0	N	437.2	N	565.9	NW	390.6	NW
Min.	52.8	SW	79.7	N	78.0	N	78.9	S

TABLE I SHOWING MILES OF WIND AND PREVAILING DIRECTION FOR EVERY DAY IN THE YEAR.

Day.	May		June		July		August	
	Miles	P. D.	Miles	P. D.	Miles	P. D.	Miles	P. D.
1	99.3	N	152.3	NE	117.3	N	49.1	S
2	132.2	N	69.4	NE	176.7	N	63.0	S
3	122.4	S	74.3	E	85.6	NE	103.7	S
4	71.5	SE	101.9	N	95.2	S	102.5	S
5	123.8	S	79.7	S	102.6	NE	77.3	S
6	186.7	S	95.7	S	82.8	S	81.0	S
7	245.6	N	299.9	S	40.7	NE	176.1	SE
8	124.2	S	159.5	W	75.7	SE	167.3	SE
9	87.2	S	95.2	E	76.2	SE	151.1	SE
10	124.3	N	96.9	S	115.5	NE	92.9	S
11	166.2	N	58.6	SW	81.5	SE	100.2	NW
12	134.3	S	64.6	E	99.8	S	46.3	S
13	79.9	N	121.1	E	128.7	E	108.3	S
14	80.7	SE	90.3	E	107.5	NE	195.2	S
15	179.4	N	116.0	S	125.0	NE	195.8	S
16	55.6	SW	224.5	SE	94.8	E	239.3	S
17	130.6	NE	198.2	SW	67.6	S	127.9	S
18	101.3	S	152.1	NE	85.5	S	95.2	E
19	34.7	NW	126.7	E	83.5	SE	127.0	NE
20	139.0	NE	118.7	NE	153.9	NE	124.7	SW
21	94.3	S	181.6	N	184.8	NE	102.7	SE
22	164.6	S	109.9	NE	220.7	N	71.7	S
23	73.8	S	84.5	E	152.3	N	92.8	S
24	114.3	SE	66.9	N	125.1	SE	91.9	SW
25	72.6	S	144.6	N	103.0	NE	266.5	S
26	64.4	NE	201.7	N	120.4	E	198.4	S
27	99.6	S	83.7	S	152.6	SE	74.9	SW
28	131.1	S	109.4	SE	209.2	NE	66.1	S
29	141.3	S	91.9	NE	143.5	S	93.2	E
30	86.8	S	47.6	NE	217.5	S	91.1	NE
31	111.8	E	.....	.....	101.6	SW	117.8	E
Max.	245.6	N	299.9	S	220.7	N	266.5	S
Min.	34.7	NW	47.6	NE	40.7	NE	46.3	S

TABLE I SHOWING MILES OF WIND AND PREVAILING DIRECTION FOR EVERY DAY IN THE YEAR.

Day.	September		October		November		December	
	Miles	P. D.	Miles	P. D.	Miles	P. D.	Miles	P. D.
1	203.2	N	151.5	N	109.7	NE	71.0	W
2	190.1	N	151.6	N	191.4	N	153.0	NW
3	125.6	NE	139.9	N	53.5	NW	102.8	N
4	71.6	NE	427.5	NW	100.3	W	166.2	N
5	65.0	E	70.0	N	62.8	S	207.8	N
6	57.1	N	91.5	N	81.0	NW	315.6	NW
7	51.5	S	163.0	N	114.3	W	59.1	NE
8	73.5	NW	119.0	N	171.5	W	88.0	W
9	129.1	SE	85.0	NW	101.0	NW	197.2	W
10	92.2	S	129.0	NE	131.0	NW	163.4	NW
11	91.0	E	84.5	NE	129.7	N	155.6	W
12	101.8	NE	120.5	N	191.3	N	260.0	NW
13	73.9	SE	74.2	NE	155.6	N	100.2	N
14	139.7	S	86.0	NE	337.0	N	91.3	NE
15	185.7	S	36.0	E	32.3	NW	114.8	N
16	202.3	S	43.9	W	97.5	W	252.2	NW
17	101.8	NE	100.0	N	97.3	N	131.6	NW
18	87.4	E	152.5	NE	109.4	N	203.4	N
19	60.7	E	155.2	NE	91.0	N	192.1	N
20	64.9	S	90.8	N	68.9	N	235.8	NW
21	3.3	SW	179.5	N	126.1	NE	144.7	N
22	49.5	N	204.5	N	109.4	NE	177.4	W
23	170.8	SW	193.4	N	75.1	N	125.7	NW
24	184.5	N	225.3	N	77.7	N	311.5	NW
25	134.0	N	105.0	E	93.8	N	148.0	SW
26	76.2	NW	226.9	S	206.4	SW	79.5	NE
27	142.5	NE	179.1	N	263.5	W	114.3	W
28	6.8	N	48.5	NE	303.2	N	302.9	NW
29	84.5	N	64.5	E	132.7	N	164.2	W
30	163.4	NE	69.3	E	84.9	N	201.1	NW
31	.....	.....	312.8	N	.....	.....	81.3	NW
Max.	203.2	N	427.5	NW	337.0	N	315.6	NW
Min.	3.3	SW	36.0	E	53.5	NW	59.1	NE

TABLE G. SHOWING THE NUMBER OF TIMES THE WIND WAS RECORDED IN VARIOUS DIRECTIONS IN EACH MONTH AT THE HOURS 7 A.M. 2 P.M. AND 10 P.M.

	N			NE			E			SE			S			SW			W			NW		
	7	2	10	7	2	10	7	2	10	7	2	10	7	2	10	7	2	10	7	2	10	7	2	10
January	15	14	18	1	2	2	0	3	0	1	3	3	0	5	2	0	0	0	3	0	1	9	2	5
February	22	18	16	2	7	4	0	1	3	0	1	0	0	1	3	0	0	0	1	0	0	4	1	3
March	17	12	6	0	3	7	2	2	6	0	1	5	1	8	7	0	0	1	1	0	1	7	2	5
April	12	5	9	1	6	3	1	6	1	1	1	1	2	9	9	1	0	1	3	0	0	6	3	3
May	8	3	3	2	5	1	2	2	1	3	4	7	1	15	11	3	0	1	5	2	0	2	0	2
June	12	3	4	5	6	3	3	0	1	0	5	3	1	8	8	2	1	2	2	0	1	5	0	1
July	7	5	1	9	8	3	1	2	5	3	9	7	1	5	9	2	0	3	0	0	1	1	1	0
August	10	2	1	1	4	1	0	0	3	1	8	1	6	11	13	3	2	3	3	1	0	3	0	1
September	18	5	8	1	8	0	1	2	1	1	1	5	1	8	7	1	0	0	1	0	2	2	1	5
October	17	15	15	1	8	1	0	3	3	0	2	2	1	2	0	0	1	1	0	0	1	12	0	8
November	18	9	11	0	3	2	2	2	0	0	3	0	1	4	0	1	2	1	2	2	9	6	2	6
December	10	13	8	0	0	0	0	1	1	1	1	0	1	3	1	2	0	1	6	1	8	10	9	11
Years	167	104	106	23	64	33	17	30	32	14	49	32	20	81	70	17	6	16	33	6	24	66	21	50
Totals	375			110			79			95			171			39			63			137		

TABLE L. THE NUMBER OF TIMES THE WIND REGISTERED A VELOCITY OF 20 MILES PER HOUR OR OVER FROM VARIOUS DIRECTIONS.

Month	N	NE	E	SE	S	SW	W	NW	TOTAL
January	5	...	...	...	...	...	...	2	7
February	5	...	...	...	...	...	...	4	12
March	2	...	...	1	2	...	...	4	9
April	4	...	...	...	4	1	...	1	10
May	1	...	...	...	1	...	...	1	3
June	1	...	...	1	...	...	...	...	2
July	...	...	...	...	...	...	...	...	0
August	...	...	...	2	3	...	...	...	5
September	..	...	...	...	2	...	...	...	2
October	3	...	...	...	...	...	...	1	4
November	5	...	...	...	...	2	...	2	9
December	8	...	...	...	...	1	2	9	20
Total	37	0	0	4	12	4	2	24	83

TABLE M. SHOWING TOTAL MILES OF WIND IN EACH MONTH FROM VARIOUS DIRECTIONS.

Month	N	NE	E	SE	S	SW	W	NW
January	3126.0	278.1	118.1	66.3	4.4	136.8	231.2	685.5
February	4470.5	4[illegible].9	112.2	0	237.2	0	67.3	435.0
March	2275.4	654.4	348.6	278.[illegible]	788.5	58.5	101.6	1027.0
April	1850.1	457.4	544.0	[illegible].5	1[illegible].5	434.9	145.6	792.9
May	644.5	212.9	2[illegible].0	3[illegible].3	1757.9	132.6	34.7	192.0
June	430.7	771.9	[illegible].3	7[illegible].2	731.8	108.1	15[illegible].6	193.7
July	779.9	[illegible]9.6	21[illegible].8	7[illegible].6	916.0	136.9	0	0
August	68.1	32.1	261.1	[illegible].5	2054.2	188.4	13[illegible].3	25.5
September	1165.7	763.8	154.1	362.1	780.2	85.2	25.0	182.8
October	2623.6	[illegible]5.0	121.0	50.6	141.5	0	130.0	503.8
November	2[illegible]8.8	108.2	23.2	152.6	128.[illegible]	447.9	142.1	772.3
December	1[illegible].2	0	22.5	131.1	115.8	215.1	652.8	2158.5
Total	21822.5	5527.3	2672.7	3505.4	9008.7	1944.4	1829.5	6369.0

Chart N°5

Showing the prevailing direction of the wind during the months of the year 2540 (1880)

第五圖

紀元二千五百四十年（明治十三年）各月中風ノ方向ノ畫

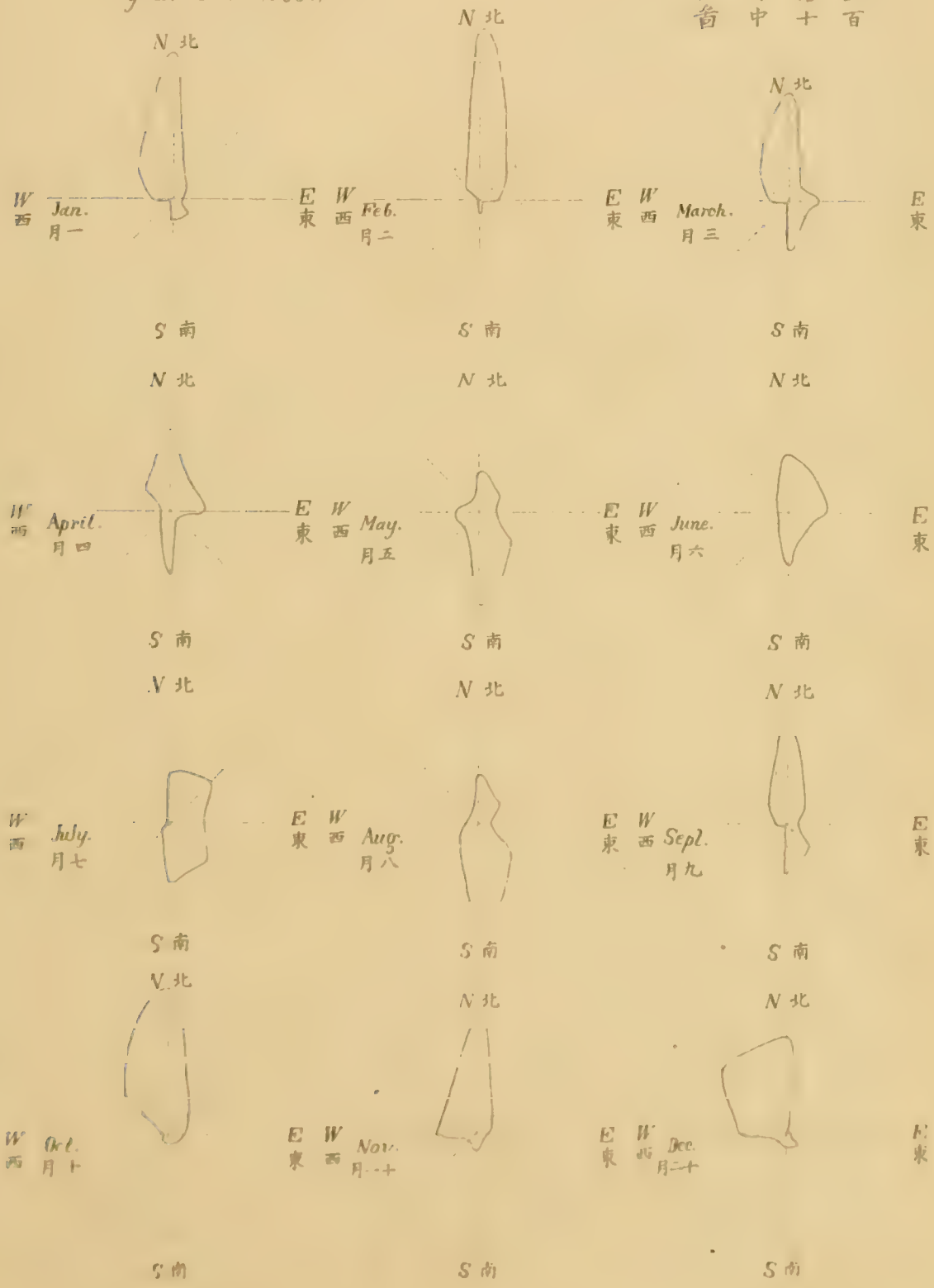


Chart N°6

Showing the number of miles of wind from various directions during the months of the year 2540 (1880)

第六圖

紀元二千五百四十年明治十三年各月中風行分量英里二三

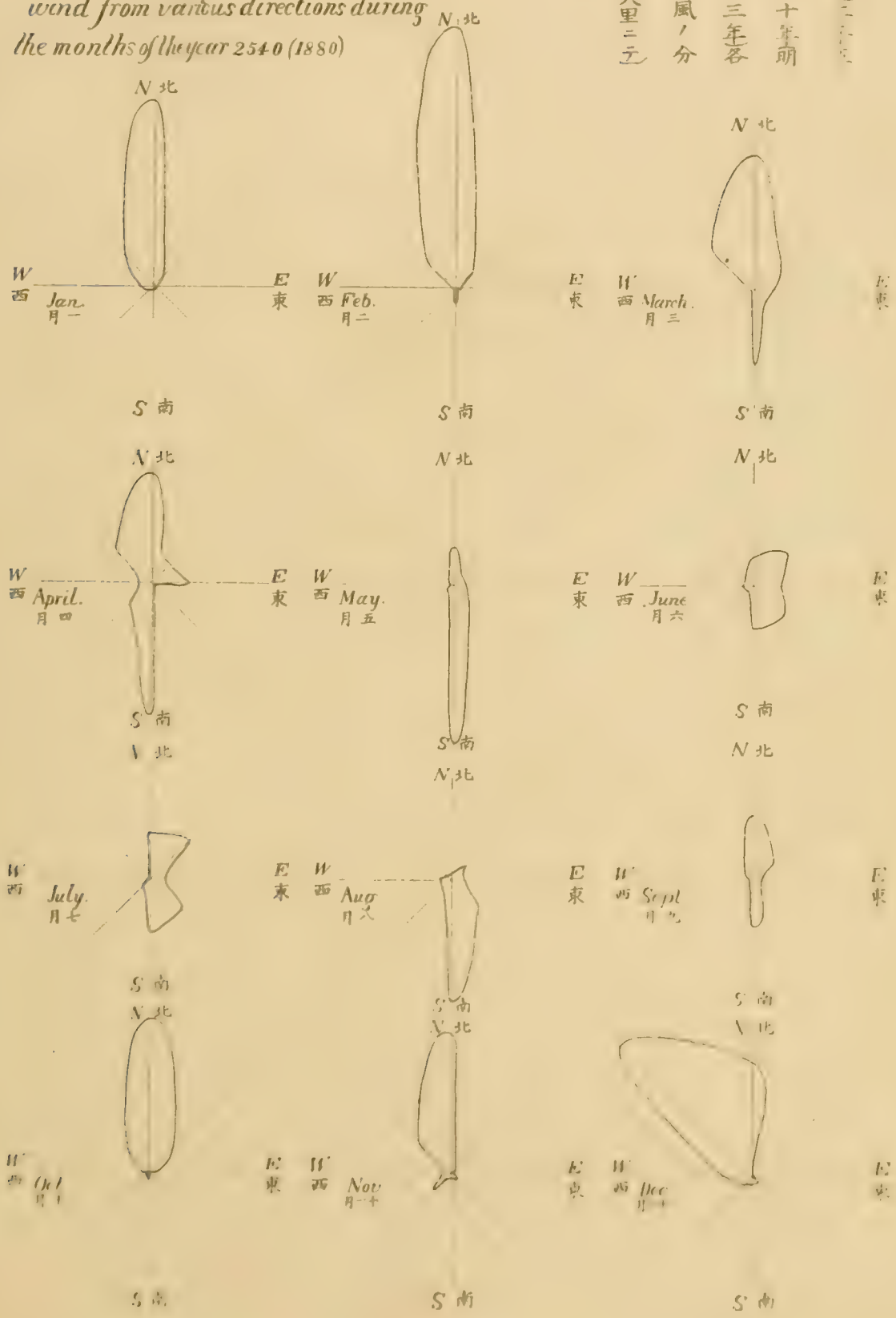


Chart N°7

Showing the prevailing direction
for the wind during the year 2540(1880)

N 北

第七圖

紀元二千五百四十年（明治十三年）中風ノ方向ヲ示ス圖

Chart N° 8

Showing the relative number of miles of wind from various directions during the year 2540(1880)

Chart No 9

Showing the relative number of times the velocity of the wind was in excess of 20 miles per hour from various directions during the year 2540 (1880)

Chart No. 10

Showing 1st the general course of the wind during the year 2540 (1880)
2nd the number of miles of wind during the months of the year

第十圖

第一紀元二千五百四十年（明治十三年）中風ノ勢方向ノ畫

第二同年各月中風ノ分量（英里ニテ）ノ畫

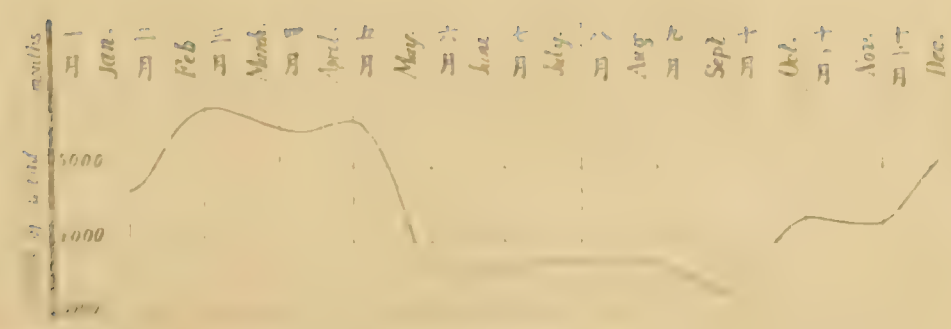


Chart N.o 5a.

Showing the prevailing direction of wind Mean of 2539 and 2540 (1879 and 1880)

第五圖甲

紀元二千五百三十九年四十(明治十二年)平均各十三年月中風ノ方向ノ圖

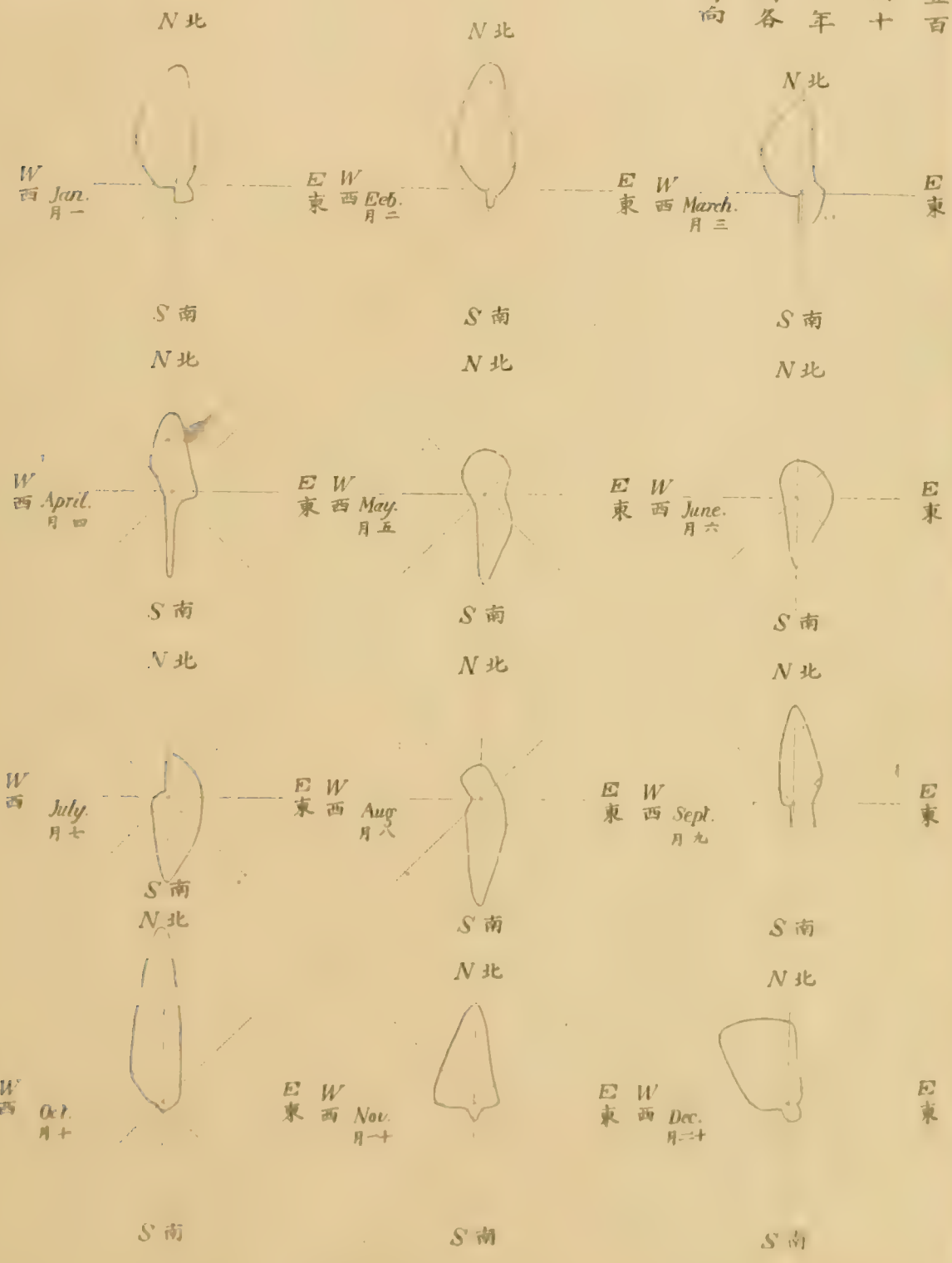


Chart No. 6a.

Showing the number of miles from various directions Mean of 2539 and 2540 (1879 and 1880)

第百六十四年中風ノ分量各月十年平均英里ニテ

紀元二千五百十九年明治十年

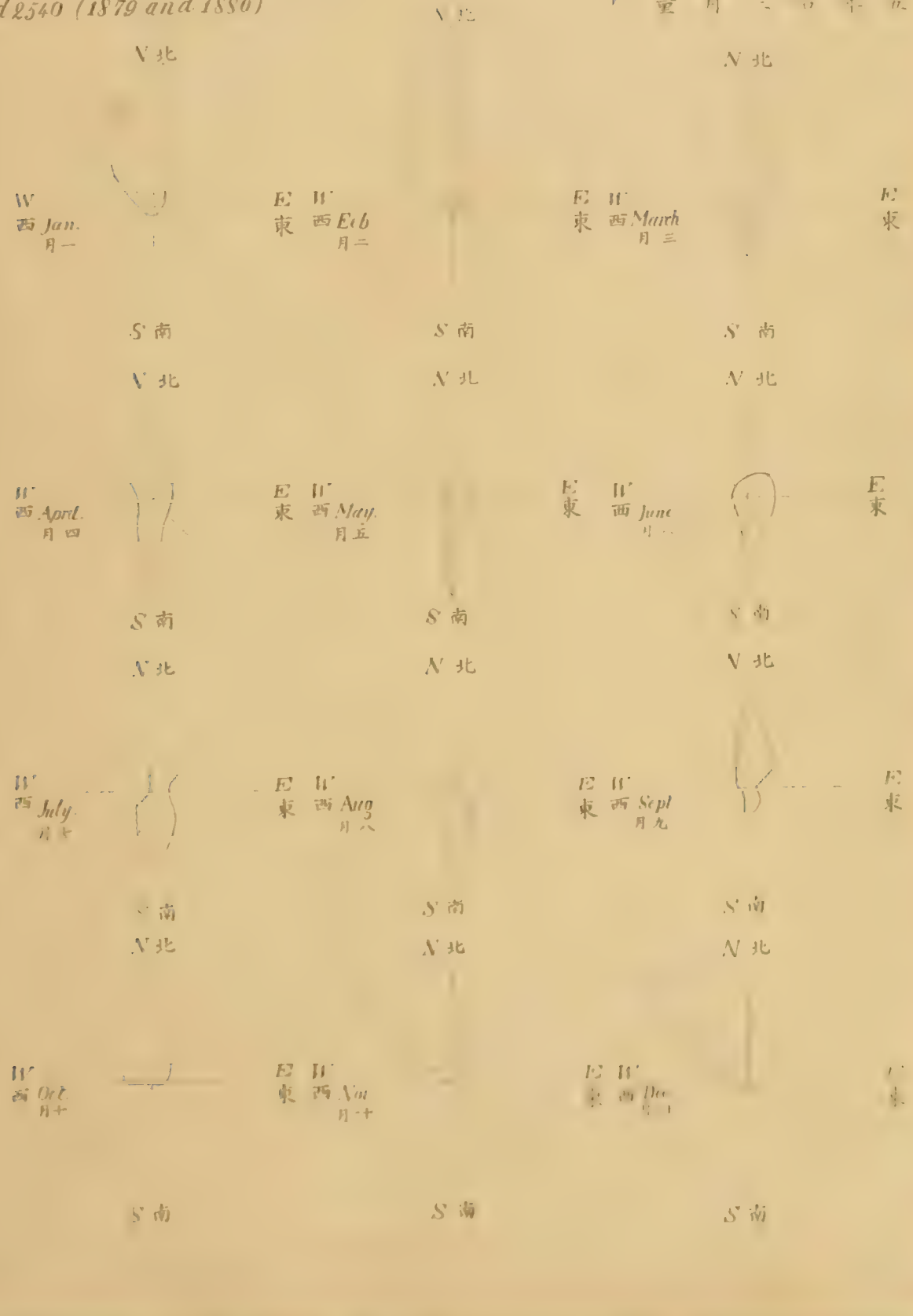


Chart N°7a.

Showing the prevailing direction of wind Mean of 2539 and 2540 (1879 and 1880)

第七圖甲

紀元二千五百二十九年明治四十年十二年十三年平均風ノ方向ノ圖

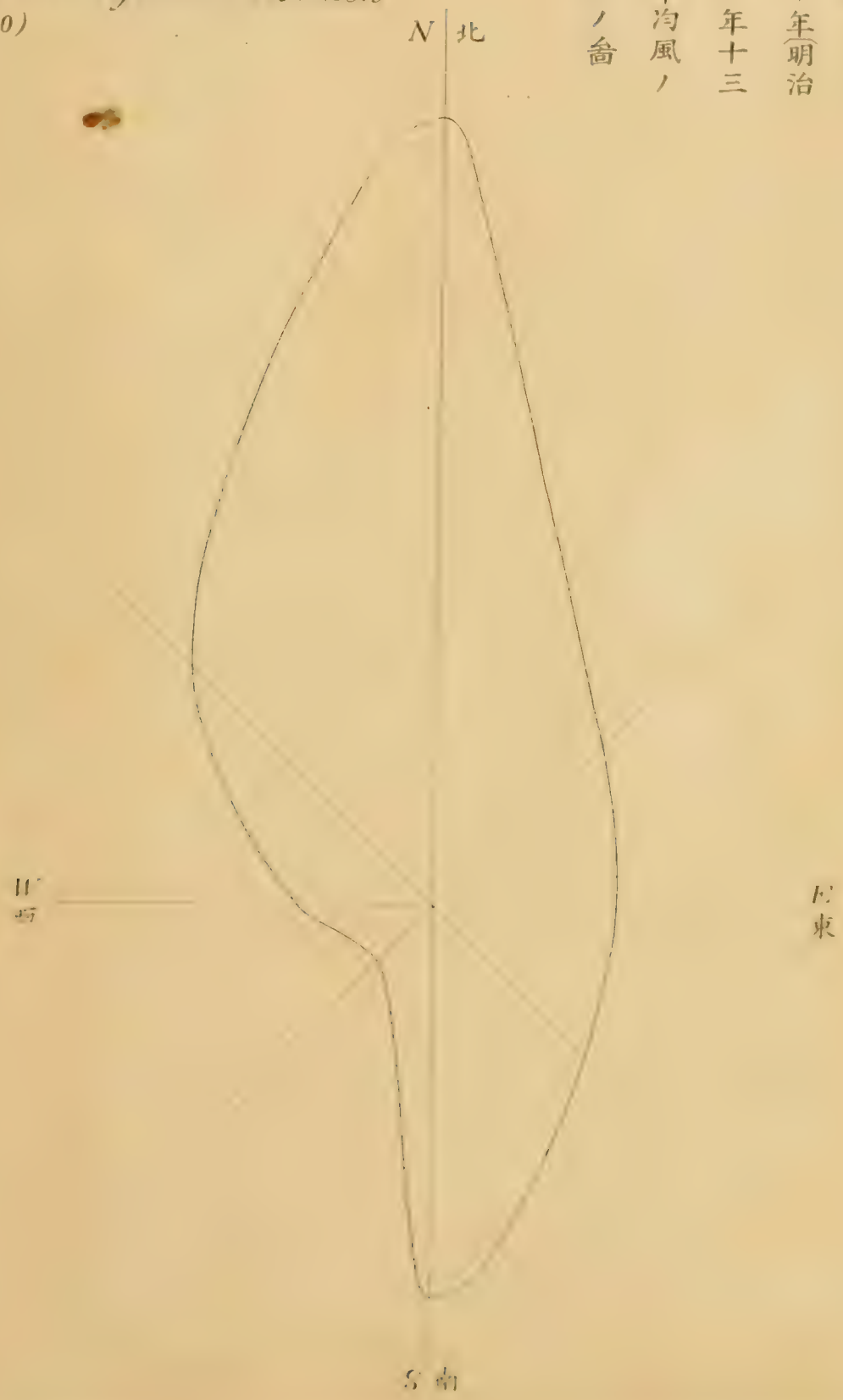


Chart No. 8a.

Showing the relative number of miles of wind from various directions
Mean of 2539 and 2540 (1879 and 1880)

第八圖甲

紀元二千五百三十九年明治四十二年十三年平均風ノ分量比較圖

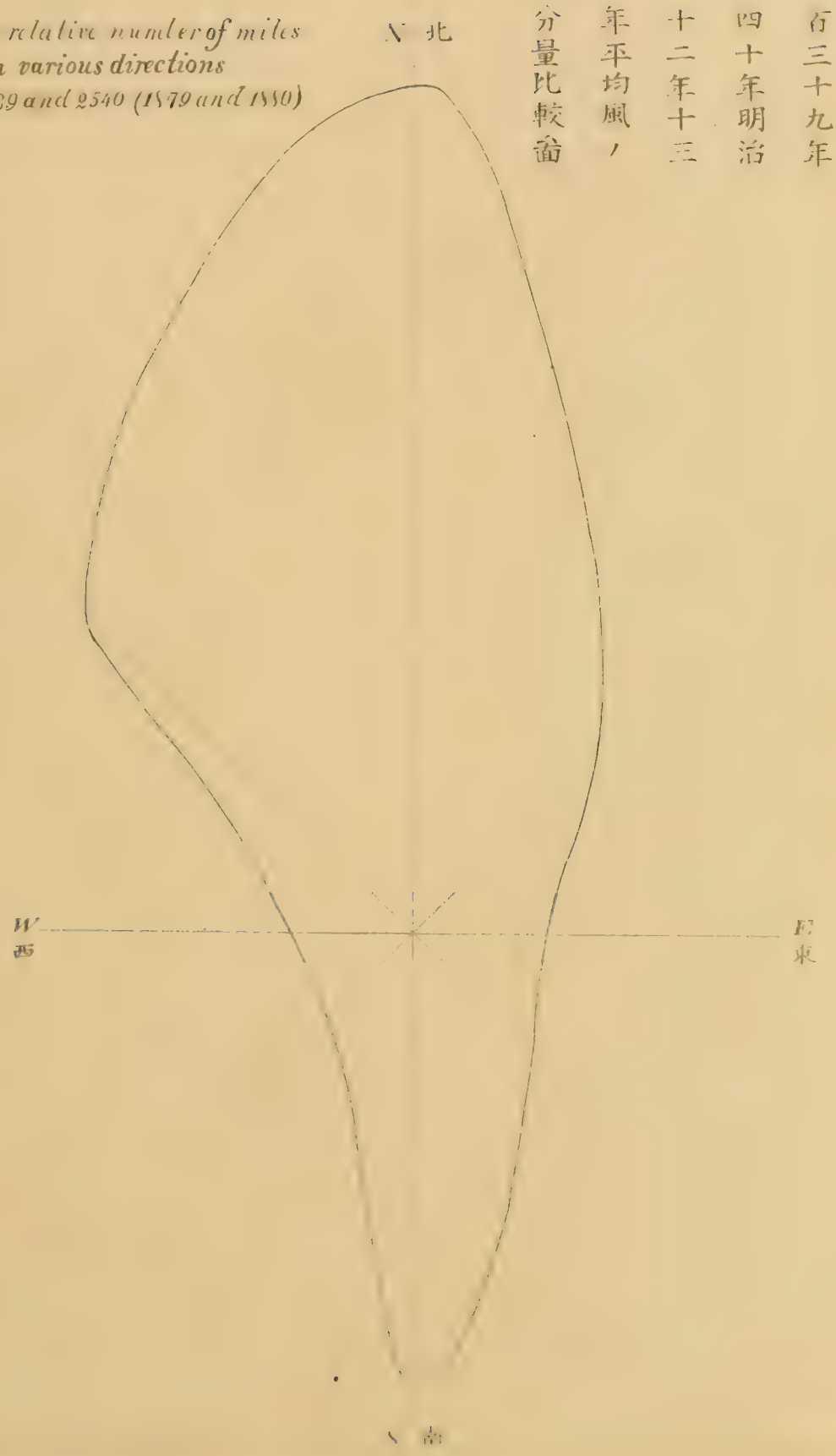


Chart No. 9 a.

Showing the relative number of times the velocity of the wind exceeded 20 miles per hour Mean of 2539 and 2540 (1879 and 1880)

紀元二千五百三十九年及二千五百四十年（明治十二年十三年）平均一時二十英里以上ノ速度ニ達シタル風ノ比較数ノ畫

Chart No. 10 a.

1st. Showing the general course of the wind Mean of 2539 and 2540 (1879 and 1880)
2nd. Showing the number of miles of wind during each month Mean of 2539 and 2540 (1879 and 1880)

第一 紀元二千五百三十九年ヨリ
二千五百四十年明治十二年十三年平均風ノ總方
向ノ圖
第二 同年々平均各月中風ノ分量
ヲ里ニテ示ス圖

A

B

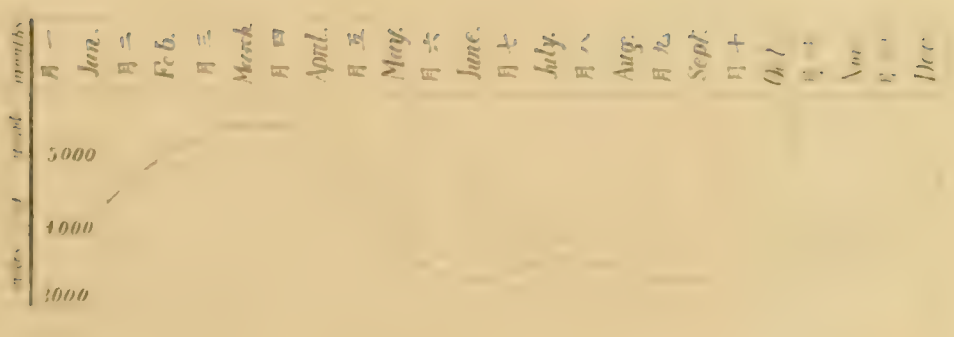


Chart N.º10 c.

Showing the height of the barometer from 7A.M. on the 3rd to 2P.M. on the 4th of October, 1880.

紀元二千五百四十年(明治十三年)十第十月三日午前第七時ヨリ翌同四日午後第二時迄晴丙雨計昇降ノ圖

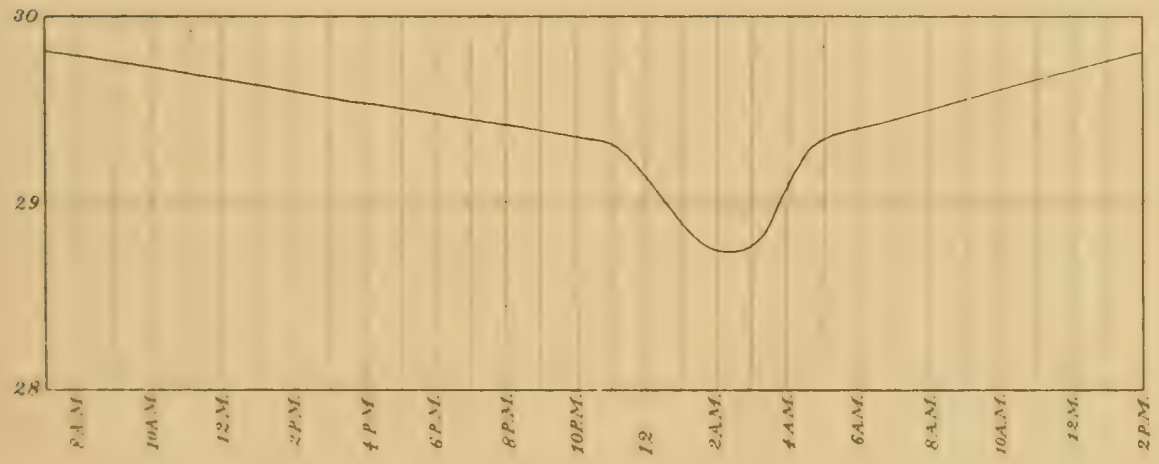
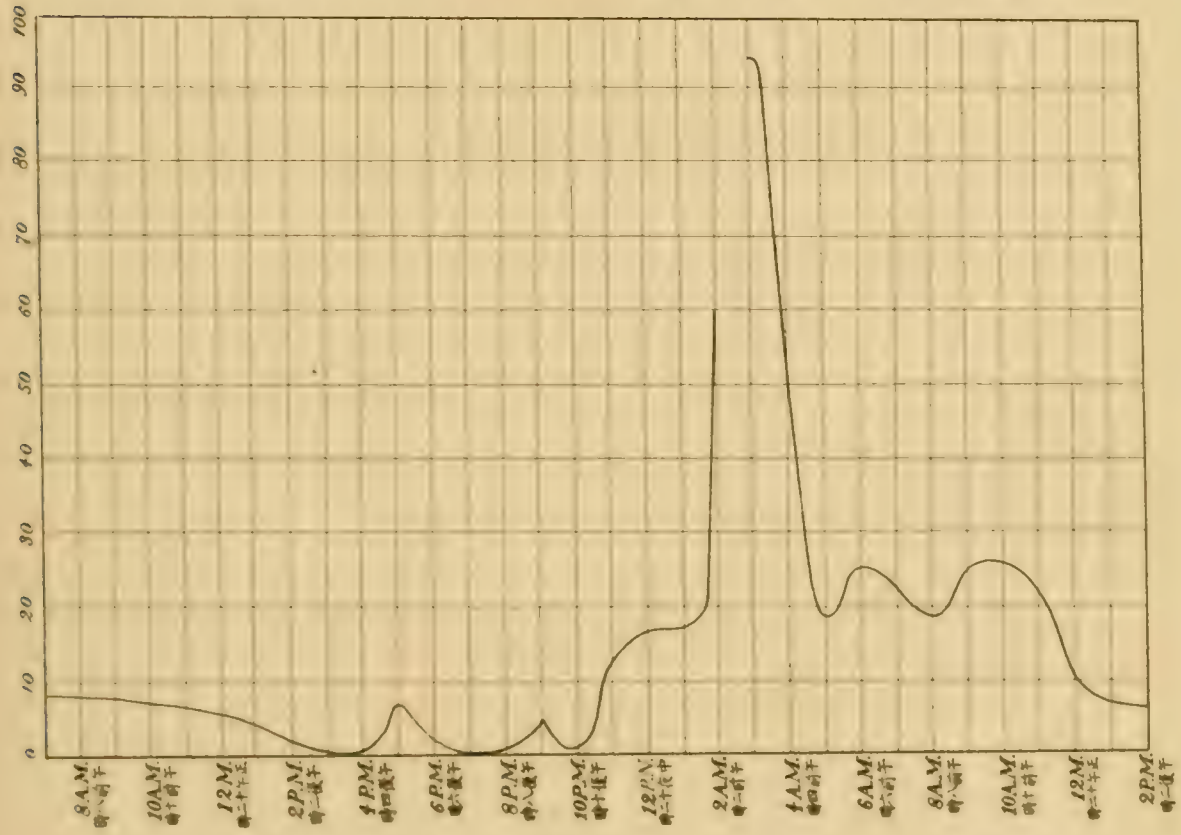


Chart N°10d.

Showing the velocity of wind from 7A.M. on the 3rd to 2P.M. on the 4th of October, 1880.

第十番丁

紀元二千五百四十年（明治十三年）十月三日午前第七時ヨリ同四日午後第二時迄風速ノ番



Note.—The break in the curve between 2A.M. and 3 A.M. representing the velocity of the wind is due to the fact that, between those hours, the registering apparatus connected with the anemograph was not in motion.

解說

四日午前第二時ヨリ同第三時ノ間器械動カズ番中ノ曲線二時ヨリ三時ノ間接續セザルヲ致ス

RAIN AND HUMIDITY.

The total rainfall for the year was 62.899 inches, an increase of almost exactly 4 inches over that of 1879. The greatest amount in any month was 9.465 inches in June, which is slightly less than the amount for June of last year, that being also the month of maximum rainfall. The smallest amount in any month fell in December, being only .016 inches. In 1879 the rainfall was smallest in November, the amount being, however, more than 2 inches. The greatest amount recorded in any one day is to be found under date of October 4th although the fall really took place on the night of the 3rd. The fall was excessively heavy during the short time that it lasted and was accompanied by a high wind which at once developed into the typhoon of that date to which reference is made in a preceding part of this report. The maximum number of days in succession on which rain fell, was 8,—from July 25 to August 1—and also from August 5th to August 12th. The maximum number of days in succession on which rain did not fall was 17, from January 4th to January 20th; and from January 4th to February 6th there was only one day on which a measurable quantity of rain fell, the amount then being but one tenth of an inch. The total number of days on which rain fell during the year was 160, against a total of 156 for the year 1879.

Of snow,—a trace is recorded on February 22nd and also on February 29th, and on March 2nd the amount measured was 1.386 inches (melted). Snow fell at no other time in the year.

All of the important facts connected with the rainfall are exhibited in tables N, O, and P and in charts 11 to 16, constructed from these tables, and others, as were the corresponding charts in the report for last year. In chart Number 11 the rainfall for every day in the year is shown, the actual amount of the rain being equal to the length of the corresponding line in inches. In charts 12, 13, 14, and 15 the distribution of the rain according to the direction of the wind is shown, both as to the number of rains and the actual amount of the fall. The first diagram in chart Number 16 shows the relative number of rainy, cloudy and clear days in each month and the second exhibits the total rainfall in inches. The fall of rain is probably more difficult than any other meteorological phenomenon to reduce to any great degree of regularity. A comparison of these charts with those corresponding for the year 1879 will show, however, that some degree of periodicity and regularity may be assumed for the rainfall of this locality. In charts 14 and 15 the results for the whole year are shown and when placed side by side with those of the year 1879, they strengthen greatly the conclusion reached in the last report, that by far the greater part of the rain comes from the North and Northwest. The curves for 1880 have shifted around towards the North, which is in exact accordance with the shifting of the wind as shown in the wind charts. When, however, comparison is made

between the curves for the months of the year 1880 with those for the year 1879, considerable irregularity will be observed. This irregularity is most marked in the summer months; thus, in June 1880 most of the rains came from the North and Northeast while in June 1879 the greater number came from the South and Southwest. For the winter months the curves show a difference in magnitude rather than in direction, although they also show a general shifting from the Northwest to the North.

The second diagram of chart Number 16 is quite similar in form to the corresponding curve for 1879. Both show three maximum rainy periods, the first in February or March, the second, and by far the greatest in June and the third in October. The inconstancy of the rainfall in the summer months is strongly shown, however, in that July, which represents a minimum point in the curve for 1879, almost reaches the greatest maximum in 1880 and September becomes a minimum instead.

Table R shows the mean percentage of humidity for every day in the year and table S gives the mean and maximum and minimum for the months. The mean percentage of humidity for the year was 76.6, the lowest observed being 31. Although much rain fell in June the maximum percentage of humidity observed was 97. In the hourly observations, however, for that month a saturated atmosphere is recorded on several occasions. In the first diagram of chart Number 17 the variations in the actual force of the vapor for the various months is shown and in the second the fluctuations in the mean percentages of humidity are exhibited. It will be seen that the real force of vapor is much greater during the summer months than during the remainder of the year and also that, notwithstanding the increased temperature, the relative humidity is also, in general, greater during the summer months.

TABLE N. SHOWING RAINFALL IN INCHES FOR EVERY DAY OF THE YEAR.

Day	January	February	March	April	May	June	July	August	September	October	November	December
1	0	0	.028	0	.002	1.578	.814	trace	.183	.040	0	0
2	.095	0	*1.386	.140	0	.233	2.344	0	trace	1.284	0	0
3	.670	0	.070 *.006	1.060	0	.018	.184	0	trace	1.276	0	0
4	0	0	0	.262	.055	0	0	0	0	4.660	0	0
5	0	0	0	0	0	0	1.223	trace	.800	0	0	0
6	0	0	0	.010	0	0	trace	.100	.052	0	.505	0
7	0	.051	0	0	3.076	1.716	.025	.142	trace	0	.180	0
8	0	.650	.286	0	.001	0	.057	1.095	0	.297	0	.014
9	0	.210	trace	0	0	0	.720	.441	0	.006	0	0
10	0	.020	0	0	.583	0	.019	.638	.003	0	0	0
11	0	trace	trace	.302	0	.031	0	.210	0	0	0	0
12	0	.325	.010	.077	0	0	trace	.446	.006	.469	.070	0
13	0	0	0	.075	trace	0	0	0	0	0	.825	0
14	0	0	0	.014	0	0	.411	0	0	0	.145	0
15	0	0	0	.400	0	0	.015	0	0	0	0	trace
16	0	.560	.510	.880	.240	1.743	0	0	.595	0	0	0
17	0	.090	.097	trace	.040	.102	0	0	0	0	0	0
18	0	.020	.013	0	0	.174	0	.070	0	0	0	0
19	0	.685	.767	0	0	.163	0	.284	trace	0	0	0
20	0	.920	.730	0	0	1.251	0	trace	0	0	.041	0
21	*.100	.412	0	0	0	.874	.805	0	0	.006	0	0
22	trace	*.200	.001	.185	.698	trace	.960	0	trace	.163	0	0
23	0	0	.942	.635	0	0	0	0	0	.400	.070	0
24	0	0	0	.041	0	.225	0	trace	0	.100	0	0
25	0	0	0	0	trace	1.238	.180	.610	trace	0	0	trace
26	0	trace	0	0	.220	0	.263	.072	.666	.492	.031	0
27	0	.380	0	trace	0	.044	.017	.032	.968	0	0	0
28	0	.960	0	trace	0	.051	1.028	.012	0	0	0	0
29	0	*.045 .020	.805	.050	0	.006	.214	.660	.007	0	0	0
30	0	.....	.411	1.433	0	.017	.045	0	0	0	0	0
31	0	.....	1.087	.....	.215	.....	.033	1.568	.....	0	.....	0

TABLE O. SHOWING THE NUMBER OF TIMES RAIN FELL AND THE TOTAL AMOUNT OF RAIN IN INCHES WITH THE WIND IN VARIOUS DIRECTIONS FOR EACH MONTH AND FOR THE YEAR.

	N		NE		E		SE		S		SW		W		NW	
	No.	Amt.	No.	Amt.	No.	Amt.	No.	Amt.	No.	Amt.	No.	Amt.	No.	Amt.	No.	Amt.
January	3	.766	0	0	0	0	0	0	0	0	0	0	0	0	0	0
February	13	3.654	4	.971	0	0	0	0	1	.560	0	0	0	0	1	.920
March	9	1.757	3	.797	0	0	4	.770	2	.662	0	0	0	0	5	1.783
April	9	3.023	2	.127	5	.233	0	0	4	.963	0	0	1	.110	3	1.111
May	1	.040	3	.556	3	.992	0	0	6	3.302	0	0	0	0	2	.242
June	5	2.411	9	1.667	3	.054	4	3.513	2	.071	1	.031	0	0	4	1.718
July	11	2.622	10	4.689	4	.586	5	.810	6	.368	2	.284	0	0	0	0
August	0	0	2	1.852	2	.616	5	1.612	12	1.893	0	0	3	.201	1	.210
September	9	1.880	5	.679	1	.110	1	.001	3	.616	0	0	0	0	0	0
October	10	3.075	1	.050	1	.005	1	.155	1	.305	0	0	1	.032	3	5.571
November	7	1.750	0	0	0	0	0	0	0	0	1	.011	1	.041	1	.025
December	1	.001	0	0	0	0	1	.001	0	0	0	0	0	0	1	.014
Year	78	21.059	39	11.388	19	2.596	21	6.862	37	8.740	4	.326	6	.384	21	11.544

TABLE P. SHOWING THE NUMBER OF DAYS ON WHICH RAIN FELL, THE TOTAL AMOUNT OF RAIN AND THE NUMBER OF CLEAR DAYS FOR EACH MONTH FOR THE YEAR

Month	Amount	No. of days on which Rain fall	No. of Clear days
January	766	3	20
February	6.105	15	6
March	5.759	16	10
April	5.567	18	8
May	5.132	12	13
June	9.465	18	4
July	9.359	21	4
August	6.384	19	1
September	3.286	15	7
October	9.193	12	8
November	1.867	8	21
December	.016	3	26
Total	62.899	160	128

TABLE R. GIVING THE MEAN PERCENTAGE OF HUMIDITY FOR EVERY DAY OF THE YEAR.

Day	January	February	March	April	May	June	July	August	September	October	November	December
1	59	64	76	54	64	96	97	85	91	86	72	71
2	77	80	100	66	58	94	87	81	80	98	74	65
3	88	58	80	92	79	79	95	81	81	97	89	65
4	62	52	65	75	90	82	82	83	83	62	83	50
5	51	50	67	56	82	80	97	79	97	75	84	58
6	70	71	72	78	85	80	90	83	94	77	92	52
7	65	96	71	77	90	78	89	83	88	82	81	69
8	74	97	97	81	74	56	85	95	75	91	69	74
9	75	98	79	85	79	80	85	90	84	80	64	49
10	62	85	69	76	90	87	86	85	89	72	59	48
11	50	85	59	81	62	90	82	86	88	78	66	48
12	54	95	72	89	65	86	81	89	84	95	73	45
13	58	48	70	79	83	71	76	78	82	78	88	58
14	72	62	61	75	74	77	90	79	83	71	58	78
15	64	73	66	88	54	81	78	75	82	79	53	51
16	59	67	80	94	88	90	76	84	87	85	72	50
17	70	81	76	66	73	83	77	76	75	84	77	47
18	70	73	87	49	71	93	76	90	79	82	76	58
19	72	97	87	65	88	90	77	86	78	63	75	50
20	61	83	62	71	68	90	82	88	86	78	88	44
21	79	95	57	79	74	92	93	82	87	78	76	59
22	71	62	76	83	96	88	89	81	86	88	75	62
23	76	55	85	87	83	76	80	81	65	90	91	53
24	72	63	45	73	77	88	80	76	66	75	79	57
25	74	59	69	44	82	96	94	82	78	81	80	56
26	65	77	62	48	69	84	95	77	94	81	60	67
27	74	89	70	71	70	82	88	82	76	67	58	69
28	59	64	56	75	80	86	93	89	80	83	46	56
29	59	82	78	67	73	83	90	86	81	83	70	63
30	77	.....	59	97	73	84	87	82	73	86	64	54
31	67	.....	95	.....	94	.....	82	95	.....	61	.....	73

TABLE 8. GIVING THE MEAN, MAXIMUM AND MINIMUM PERCENTAGES OF HUMIDITY FOR EACH MONTH

Month	Means	Maximum	Minimum
January	67	95	36
February	75	100	34
March	73	100	33
April	74	97	29
May	77	100	31
June	84	97	51
July	86	100	60
August	84	98	53
September	82	100	49
October	86	100	38
November	73	97	31
December	58	95	16

Chart No. II

Showing the rainfall in inches for every day of the year 2540 (1880)

紀元二千五百四十年(明治十三年)各一日雨ノ分量ヲ寸(英寸ニテ)ノ歩ニ表ス

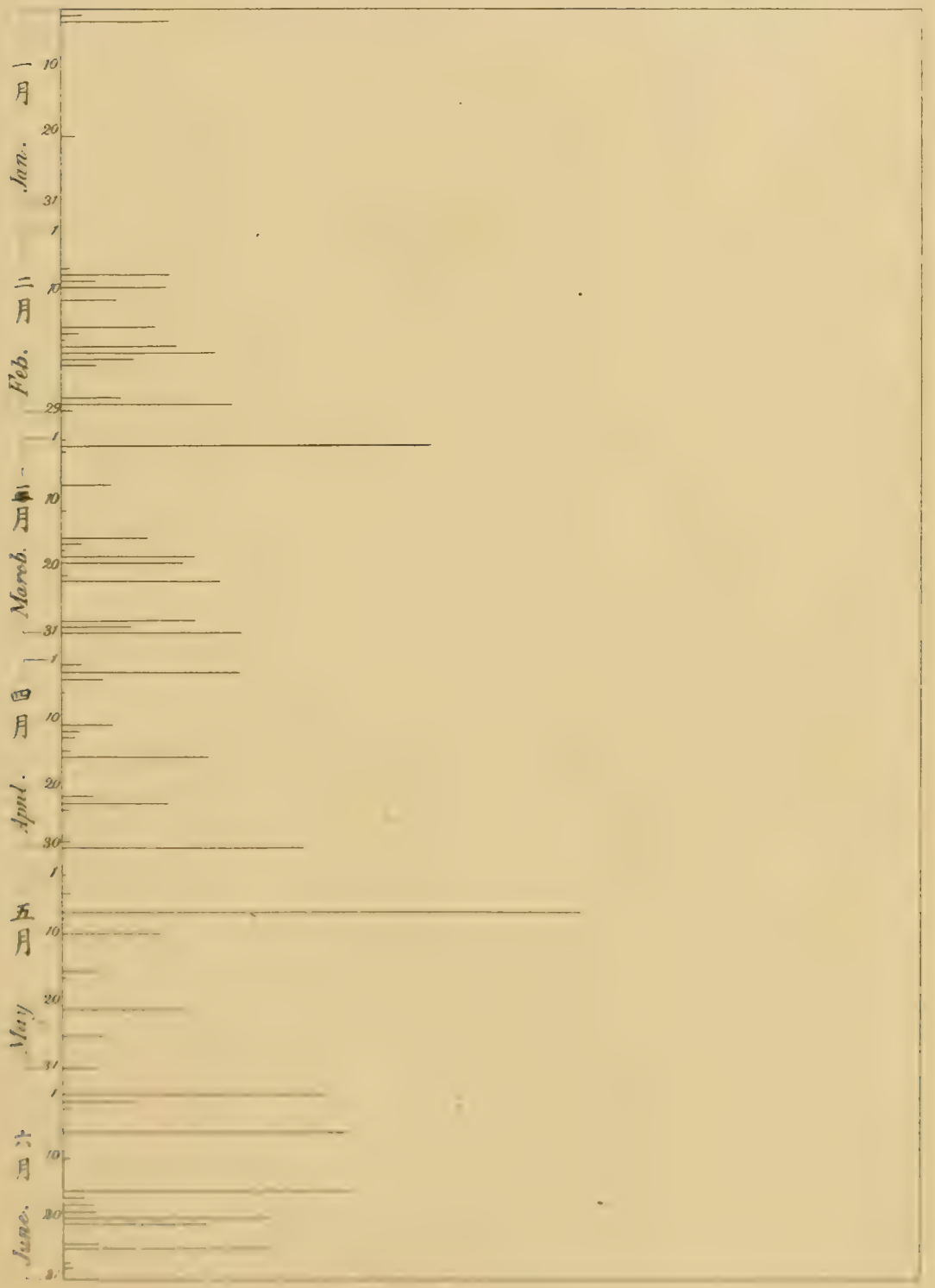


Chart No. 11

Showing the rainfall in inches for every day of the year 2540 (1880)

紀元二千五百四十年（明治十三年）各一日雨ノ分量ヲ（英寸ニテ）ノ図

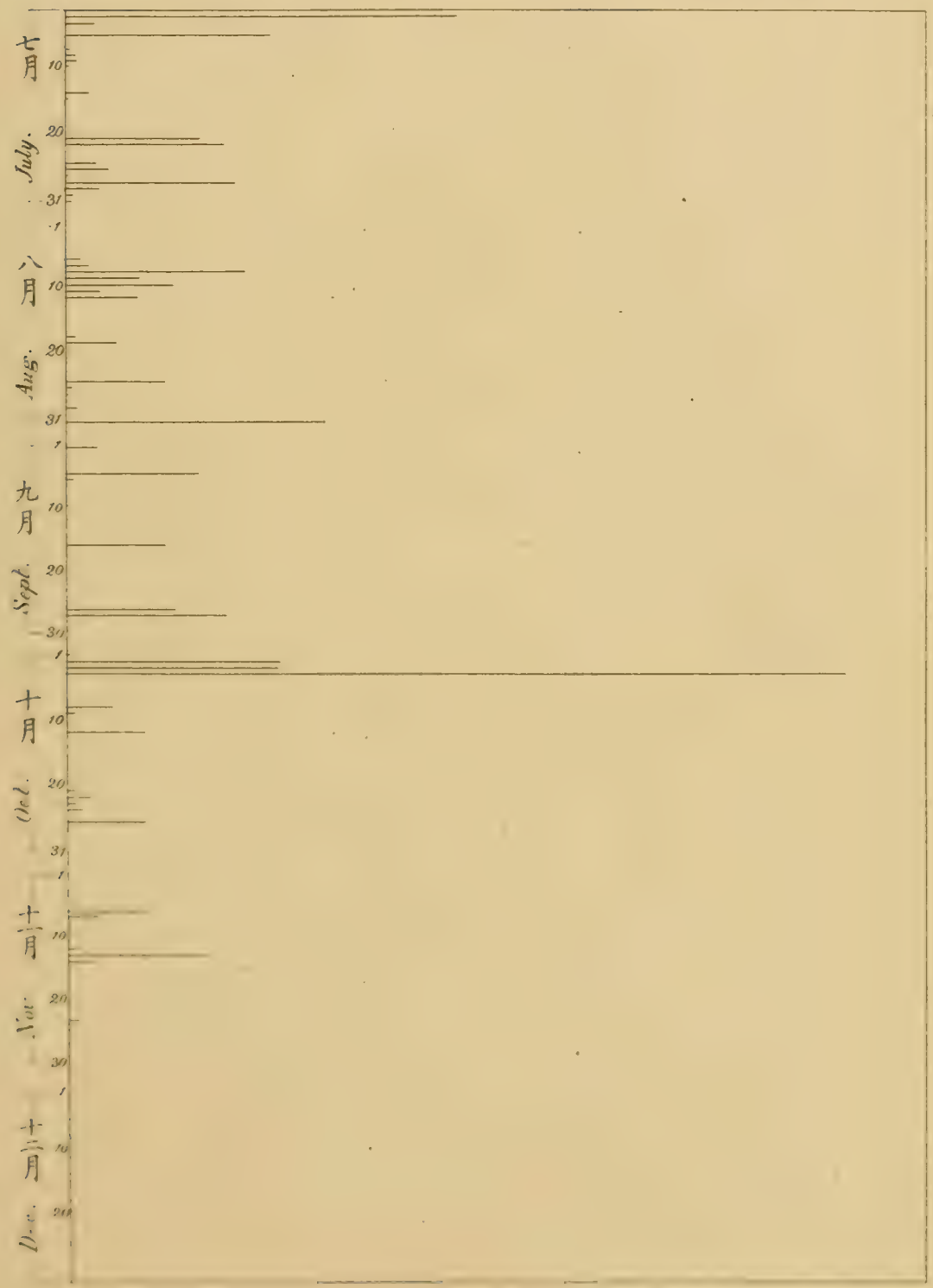


Chart No. 12

Showing relatively the number of times rain fell in each month with the wind in various directions.

第十二番

紀元二千五百四十年明治十三年ノ各月中風雨ノ日数ヲ以テ但シ雨天ノ比較ヲ算ス

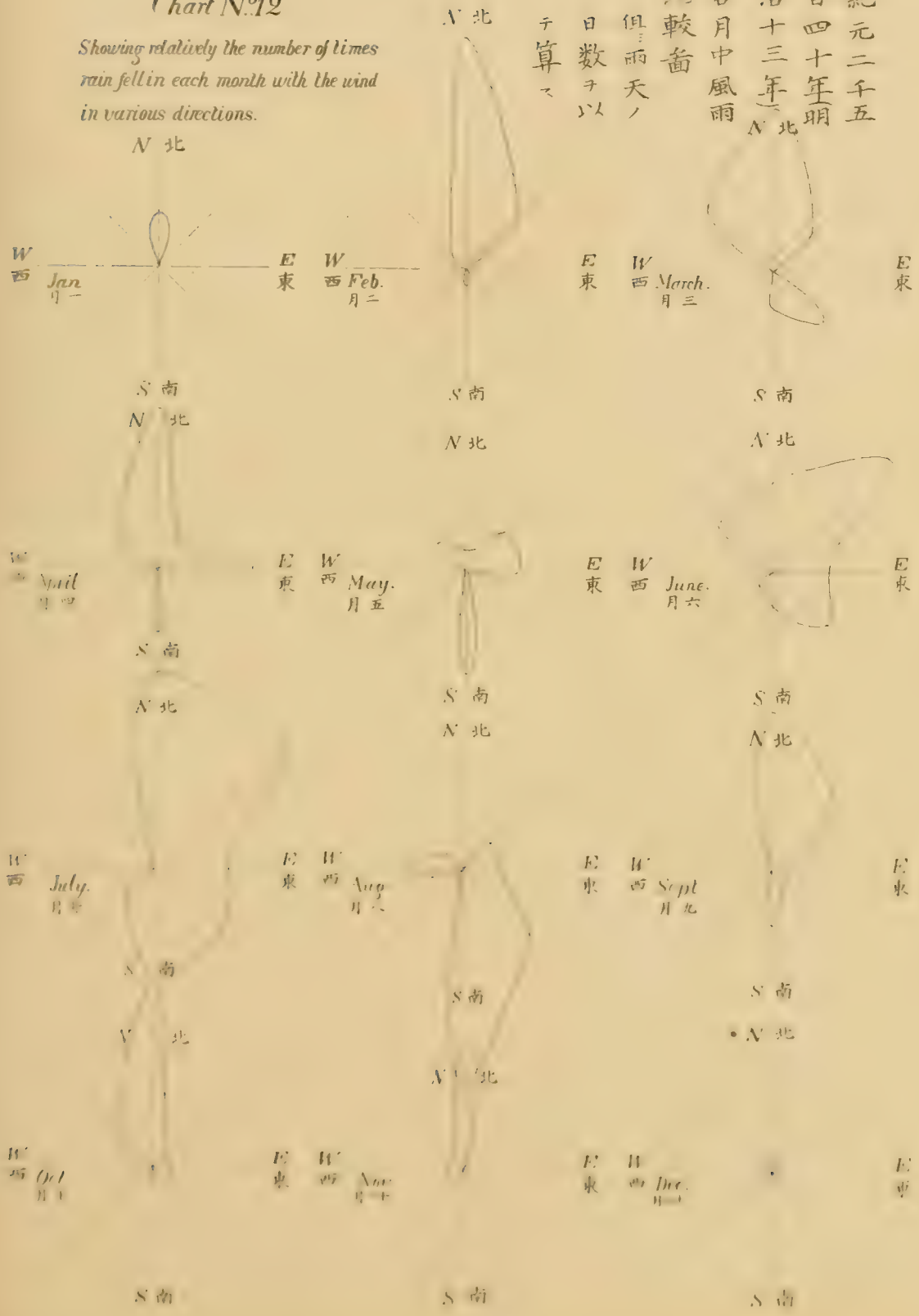


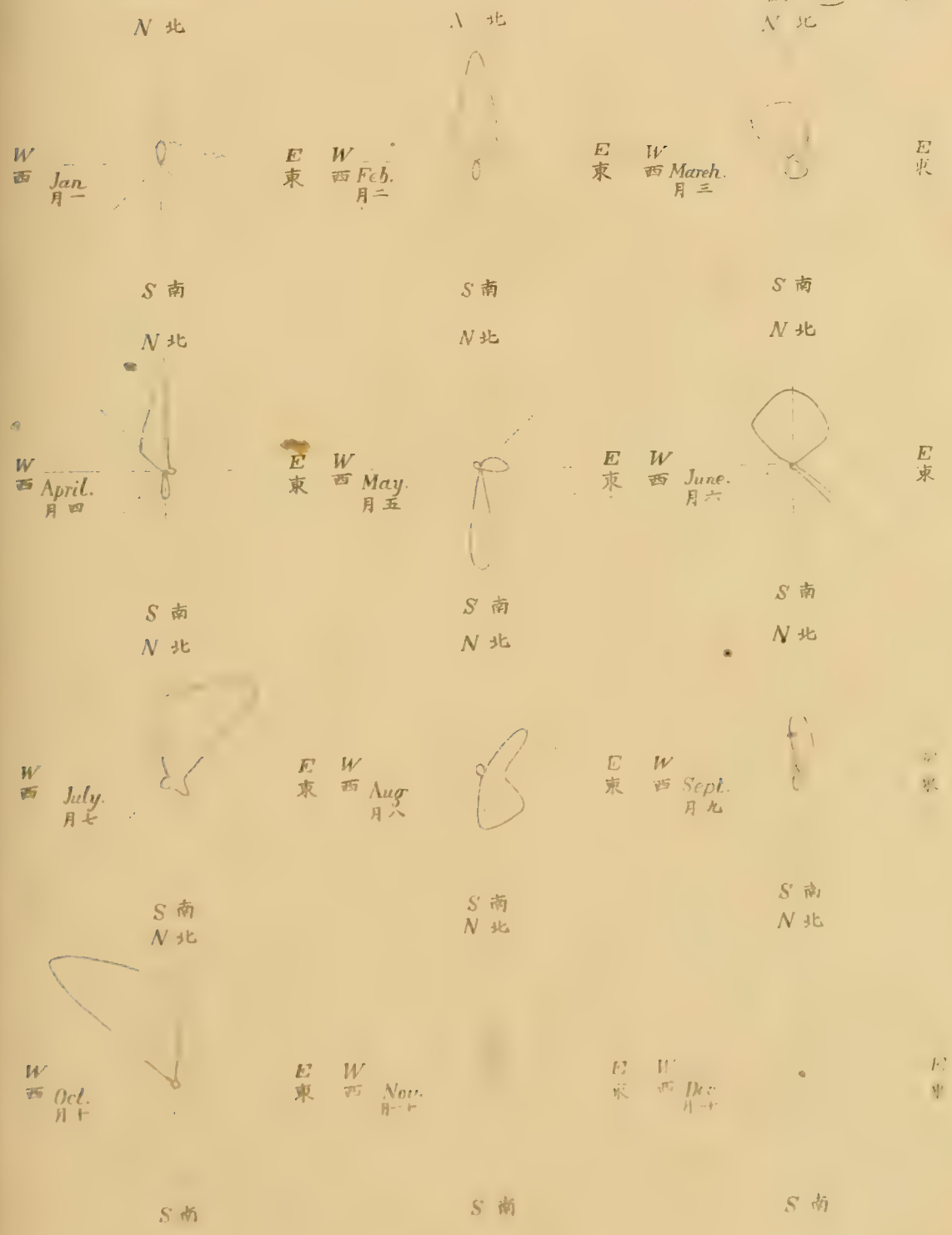
Chart N°13

Showing the relative total amount of rain in each month with the wind in various directions.

第十三圖

紀元二千五百四十年（明治十三年）各月中風雨ノ比較圖

但シ雨ノ分量ヲ以テ算ス



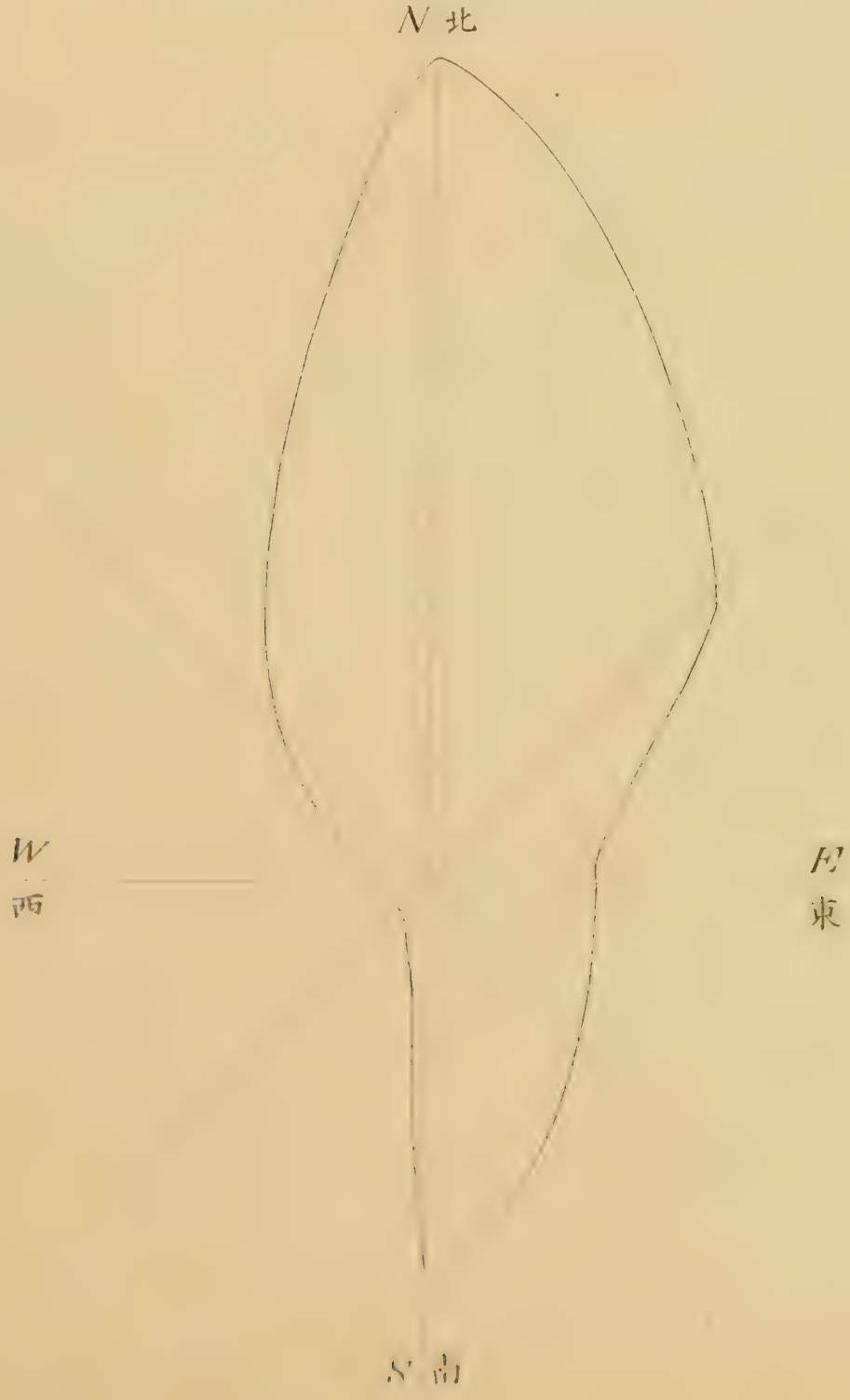
第十四圖

紀元二千五百四十年（明治十三年）中風雨比較

但雨天ノ日數ヲ以テ算ス

Chart N°14

Showing relatively the number of times rain fell during the year with the wind in various directions



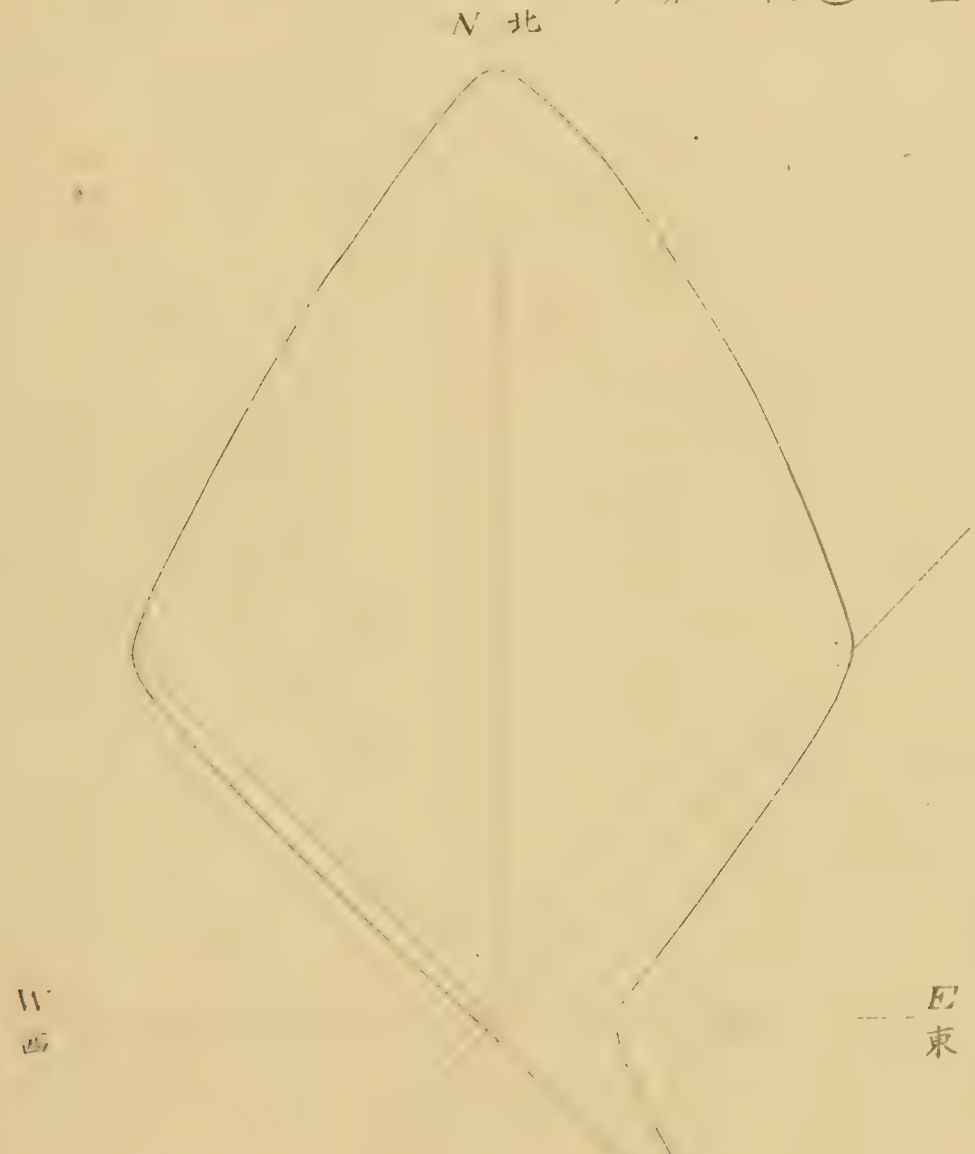
第十五畝

紀元二千五百四十年（明治十三年）中風雨比較

但雨ノ分量ヲ以テ算ス

Chart N°15

Showing relatively the number of inches of rain during the year with wind in various directions

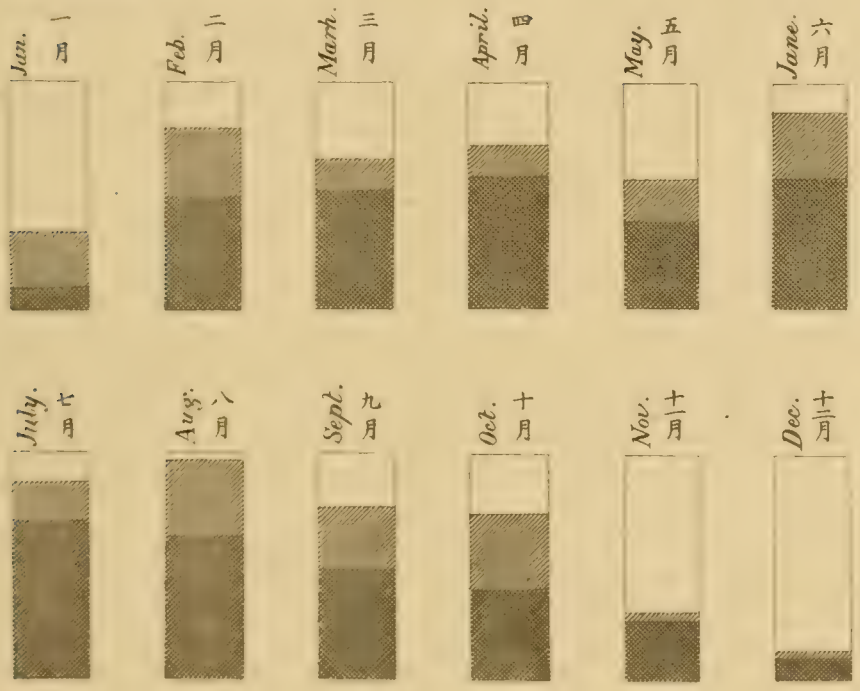


第一紀元二千五百四十年（明治十三年）中晴天曇天雨天ノ日数比較畓第二同年各月中降雨ノ全量（英寸ニテ）圖

畓 六 十 第

Chart No. 16

Showing 1st the relative number of raining cloudy and clear days in each month.
2nd the total rainfall in inches for each month



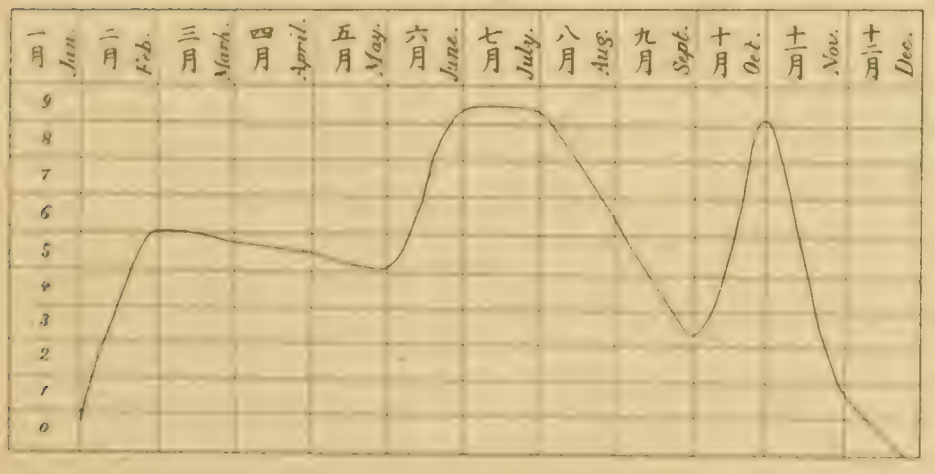
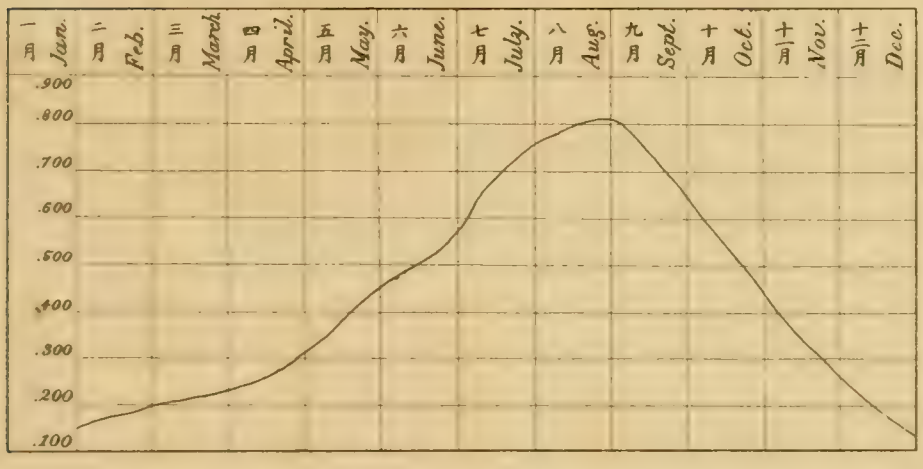
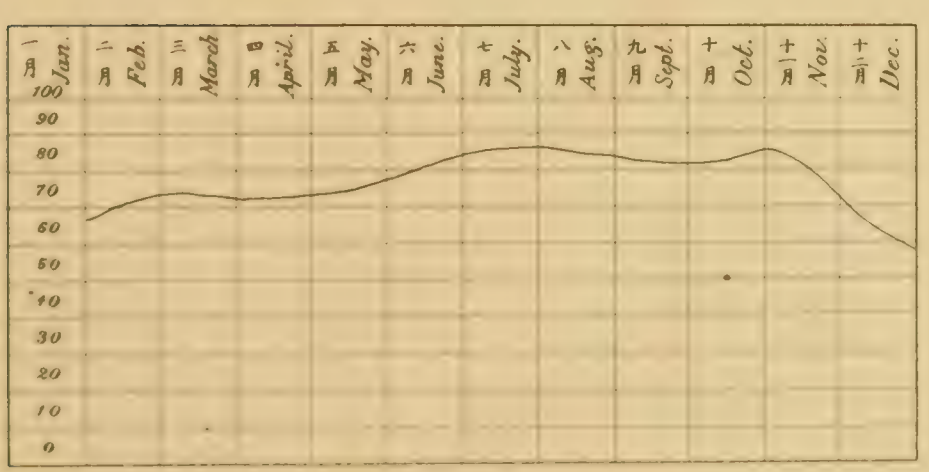


Chart N°17

Showing
1st The monthly means of theforce of vapor
2nd Themonthly means of relative humidity.

第一 二千五百四
第十年(明治十三年)
十 空中水氣力各日
七 ノ平均
畜 第二 水氣比較量
各日ノ平均畜





HOURLY OBSERVATIONS.

Hourly observations were maintained during the months of March, June, September and December. The entire series of observations is not here reproduced as the principal object was to ascertain the diurnal fluctuations. In tables T and U will be found the hourly means obtained for this purpose. Table T contains the hourly means for each month and table U the means for the whole period of four months. In this the velocity of the wind is omitted and the mean force of vapor for each hour in the day is inserted. Diurnal fluctuations are seen much more readily in charts 18, 19, 20, 21 and 22. On the two pages of chart number 18 are the barometric curves for each of the four months and also for the mean of all. Concerning the curve for the month of June and also for the table for the same month, it ought to be said that it was found necessary to reject the observations of one day. During a portion of the forenoon of June 7th the barometer readings were undoubtedly seriously in error and, as no means existed for their correction, it was considered best to reject them entirely and in consequence, the barometric observations for the entire day. The hourly means of the barometer for that month are, therefore, based on observations during 29 days instead of 30. There were no reasons for doubting the observations of temperature, humidity etc. made upon the same day and they have accordingly been retained. The barometric curves for the four months agree pretty well as to their maximum and minimum points. It is noticeable, however, that the greatest maximum appears to occur about an hour earlier in June and December than in March and September. There appears to be considerable variation in the time of the great minimum which occurs in the afternoon. In June this seems to be between 4 o'clock and 5 o'clock while in December it is as early as 2 o'clock. In a single series of hourly observations, however, the results must be largely influenced by temporary non-periodic barometric changes which sometimes are very considerable and their effect can only be eliminated by greatly multiplying the number of observations. As it was not possible to maintain hourly observations throughout the whole year, the months of March, June, September and December were selected on account of the relation which they sustain to the position of the sun. An examination of the curve exhibiting the monthly means from the regular series will show that, in general, these months were months of low barometric height and the same thing is shown in the corresponding curve in the report of last year. During the year 1881 a series of hourly observations will be carried on during those months which seem to be characterized by a high barometer and these results may, in the future, be combined with those furnished with this report.

The amount of the diurnal movement for each month is as follows;

March	.090	inches
June	.048	,,
September	.067	,,
December	.076	,,
Mean for four months	.067	,,

These numbers have the same relative magnitude as the monthly ranges for the corresponding months, except that June and September have changed places. But on June 7th, the barometric readings for which are omitted in the reduction of the hourly observations, the barometer was unusually low, and had it been possible to have made use of the records for that day the diurnal range for June would have been greater than that given above.

The temperature curves show great regularity as to their points of maxima and minima. The maximum temperature occurs at 3 p.m. in all of the months and the minimum at 6 a.m. in March and September, at 5 a.m. in June and at 7 a.m. in December.

From table T the mean daily range is found to be as follows;

March	13°.2
June	9°.8
September	11°.4
December	16°.7
Mean for four months	12°.6

These numbers have the same relative magnitudes as those representing the maximum daily range for the corresponding months, from the regular series.

The two pages of chart Number 20 contain curves representing the hourly means of the percentages of humidity observed during the same four months. This element is liable to frequent and considerable disturbances from accidental or non-periodic causes and the curves are, therefore, less regular than those representing temperature. They exhibit the same general form, however, and follow the inverse movement of the thermometer very closely. The daily range is as follows;

March	24	per.	cent.
June	18	,,	,,
September	25	,,	,,
December	35	,,	,,
From mean curve	25	,,	,,

It will be seen that the range is greatest when the actual percentage of humidity is least, and least when it is greatest. It appears from these curves that there is a time in the early morning, generally from 1 a. m. to 7 a. m., during which the percentage of humidity does not vary greatly and that the fall in the percentage of humidity lags somewhat behind the rise in the thermometer.

Chart number 21 shows the hourly means of the force of vapor for the same time. These, like the curves of relative humidity, are somewhat irregular but are in fair agreement as to their general form. The daily range in no case exceeds one tenth of an inch and in the curve for the mean of the four months it is almost exactly one half of that amount.

Table V contains the mean barometer and the mean temperature for every day of March, June, September and December as obtained from the hourly observations.

TABLE T. MEAN BAROMETER, TEMPERATURE, RELATIVE HUMIDITY AND VELOCITY OF THE WIND FOR EACH HOUR.

Hour	March				June			
	Baro.	Temp.	Hum.	Veloci.	Baro.	Temp.	Hum.	Veloci.
1	30.026	43.6	78	6.3	29.828	64.3	91	3.0
2	30.022	42.8	80	6.5	29.824	64.1	91	3.7
3	30.012	42.0	82	7.0	29.823	63.8	92	3.5
4	30.011	41.2	81	6.0	29.828	63.4	92	3.5
5	30.019	40.7	81	5.9	29.840	63.2	93	3.3
6	30.031	40.4	82	5.3	29.848	63.7	92	3.5
7	30.043	40.7	81	6.1	29.858	64.8	90	4.1
8	30.055	42.6	77	5.8	29.863	66.2	88	4.7
9	30.061	45.2	69	7.6	29.861	68.0	83	4.7
10	30.061	47.4	66	9.0	29.859	69.5	80	4.9
11	30.047	49.4	63	8.5	29.853	71.0	77	5.3
2m	30.026	51.2	62	9.0	29.847	72.1	76	5.0
1	30.003	52.5	59	8.3	29.834	72.8	75	5.5
2	29.978	53.4	58	9.8	29.829	72.9	76	6.2
3	29.973	53.7	60	9.4	29.820	73.0	75	6.6
4	29.971	53.0	62	9.5	29.815	72.9	75	6.7
5	29.972	51.9	65	10.0	29.815	72.2	77	6.5
6	29.981	50.2	68	8.7	39.822	71.1	78	6.6
7	29.988	48.6	73	7.2	29.834	69.7	80	5.6
8	30.002	47.5	75	7.4	29.845	68.4	83	5.0
9	30.009	46.5	77	6.6	29.856	67.3	85	4.6
10	30.012	45.8	78	6.2	29.863	66.5	87	5.0
11	30.006	45.1	79	5.9	29.860	65.8	89	3.7
12	29.998	44.6	78	6.4	29.854	65.1	90	3.8

TABLE T. MEAN BAROMETER, TEMPERATURE, RELATIVE HUMIDITY AND VELOCITY OF THE WIND FOR EACH HOUR.

Hour	September				December			
	Baro.	Temp.	Hum.	Veloci.	Baro.	Temp.	Hum.	Veloci.
1	29.974	69.0	90	3.9	29.948	34.2	70	5.4
2	29.970	68.5	91	3.8	29.952	34.0	68	5.2
3	29.967	67.9	91	3.6	29.947	33.2	70	5.4
4	29.967	67.4	92	3.3	29.944	32.5	70	5.5
5	29.974	67.0	93	3.4	29.945	32.0	71	4.9
6	29.984	66.7	92	3.4	29.954	32.0	70	5.3
7	29.994	67.6	94	3.8	29.964	31.6	71	5.6
8	29.999	69.5	87	4.6	29.973	32.7	65	4.8
9	30.005	71.7	81	5.2	29.979	36.5	55	6.5
10	30.004	73.7	77	5.3	29.976	40.2	48	8.0
11	29.988	75.4	74	5.8	29.958	43.3	41	10.1
12 m	29.975	75.9	72	5.5	29.936	45.5	38	10.8
1	29.961	77.5	71	5.3	29.906	47.5	36	11.0
2	29.947	77.8	70	5.9	29.903	48.2	37	11.8
3	29.938	78.3	69	5.9	29.909	48.3	37	10.2
4	29.940	77.7	70	6.2	29.922	47.0	42	10.1
5	29.945	76.7	72	6.0	29.934	44.5	50	7.8
6	29.956	75.1	77	4.7	29.950	42.3	55	6.1
7	29.969	73.5	81	3.9	29.960	40.5	57	6.1
8	29.986	72.5	84	3.6	29.967	39.2	60	6.5
9	29.991	71.8	85	3.1	29.972	37.7	64	5.1
10	29.992	71.1	87	3.0	29.975	36.5	66	5.1
11	29.991	70.2	88	3.5	29.972	35.6	67	5.3
12	29.987	69.5	89	3.6	29.963	34.6	69	5.7

TABLE U. MEAN BAROMETER, TEMPERATURE, RELATIVE HUMIDITY AND FORCE OF VAPOR FOR EACH HOUR FROM THE HOURLY OBSERVATIONS IN MARCH, JUNE, SEPTEMBER AND DECEMBER.

	Baro.	Temp.	Hum.	Force of vapor.
1a.m.	29.944	52.8	82	0.383
2	29.942	52.4	83	380
3	29.937	51.7	84	380
4	29.938	51.1	84	376
5	29.945	50.7	85	372
6	29.954	50.7	84	372
7	29.965	51.2	84	379
8	29.973	52.8	79	381
9	29.977	55.4	72	388
10	29.975	57.7	68	395
11	29.962	59.8	64	403
12	29.946	61.2	62	410
1p.m.	29.926	62.6	60	413
2	29.914	63.1	60	416
3	29.910	63.3	60	417
4	29.912	62.7	62	417
5	29.917	61.3	66	425
6	29.927	59.7	70	417
7	29.938	58.1	73	414
8	29.950	56.9	76	410
9	29.957	55.8	78	406
10	29.961	55.0	80	405
11	29.957	54.2	81	398
12	29.951	53.5	82	392

TABLE V. MEAN BAROMETER AND MEAN TEMPERATURE FOR EVERY DAY FROM HOURLY OBSERVATIONS.

Day.	March		June		September		December	
1	30.309	36.8	29.613	60.6	29.956	69.1	29.985	45.0
2	30.209	32.3	29.703	60.0	30.025	71.1	29.971	46.0
3	30.181	35.3	29.900	62.3	30.062	70.1	30.081	33.1
4	30.259	36.5	29.936	67.2	30.010	72.8	29.949	42.3
5	30.361	37.2	29.961	68.7	29.973	69.9	29.908	38.0
6	30.389	39.5	29.963	70.0	29.948	70.0	29.999	40.6
7	30.293	44.5	.....	73.4	29.921	75.4	30.053	38.3
8	30.055	42.6	29.537	73.5	29.989	76.0	29.790	39.1
9	30.008	44.9	29.702	70.0	30.006	74.5	29.470	40.1
10	30.101	48.6	29.823	70.0	29.832	77.0	29.501	36.7
11	30.060	49.6	29.892	67.1	29.839	77.1	29.704	40.6
12	29.956	49.7	29.886	67.5	30.016	73.7	30.061	44.7
13	29.891	49.1	29.854	68.1	30.092	74.9	30.196	43.6
14	29.762	50.3	29.942	69.1	30.034	76.1	29.981	40.8
15	29.958	49.6	28.944	71.3	29.894	77.0	29.783	40.2
16	29.973	48.5	29.749	67.2	29.752	75.2	29.876	36.4
17	29.908	57.3	29.622	69.9	30.016	79.0	30.097	40.3
18	30.024	56.3	29.657	66.0	30.054	70.9	30.034	39.1
19	29.869	58.9	29.694	66.5	30.037	73.3	29.810	38.6
20	29.450	50.2	29.774	63.5	29.952	71.9	29.907	38.0
21	30.164	43.1	29.986	61.5	29.839	74.8	29.893	35.6
22	30.291	47.8	30.188	66.5	29.797	76.0	29.880	39.0
23	29.890	47.1	30.230	67.7	29.726	79.0	29.806	38.3
24	29.918	41.6	30.098	64.7	30.101	67.8	29.916	32.3
25	30.013	45.1	29.845	64.0	30.181	67.3	30.110	33.2
26	30.010	51.7	29.782	70.1	29.962	68.9	30.113	33.9
27	29.849	51.5	29.862	72.6	30.078	67.2	29.981	35.5
28	29.774	50.5	29.800	72.3	30.038	65.9	29.822	33.6
29	29.906	47.9	29.737	73.4	29.981	66.1	30.081	34.7
30	29.856	49.8	29.767	71.2	30.117	62.9	30.327	38.3
31	29.721	48.5	.....	.....	.....	.....	30.373	35.9

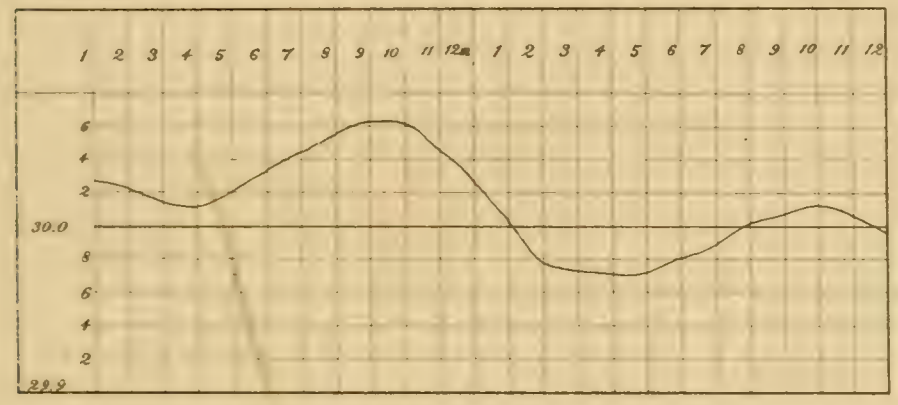
Chart N.º 18

Showing hourly means of barometer during a portion of the year.

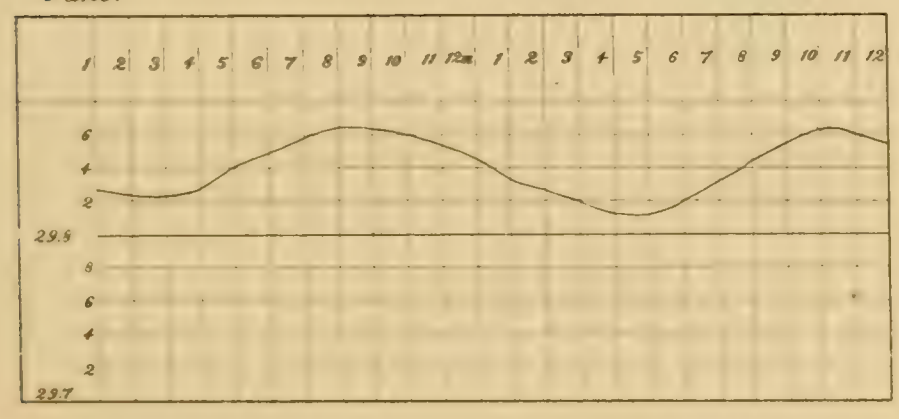
第十八圖

二千五百四十年明治十三年三月六日ヨリ十二月四ケ月中晴雨計各時觀測平均ノ圖

March. 三月



June. 六月



September. 九月

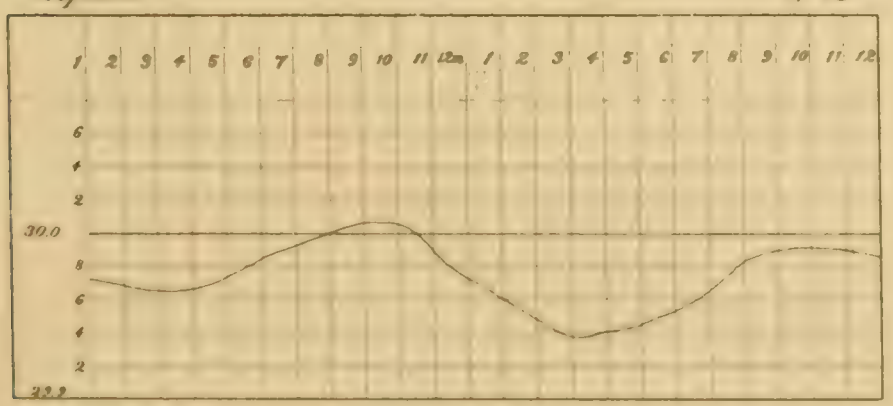


Chart N.º 18

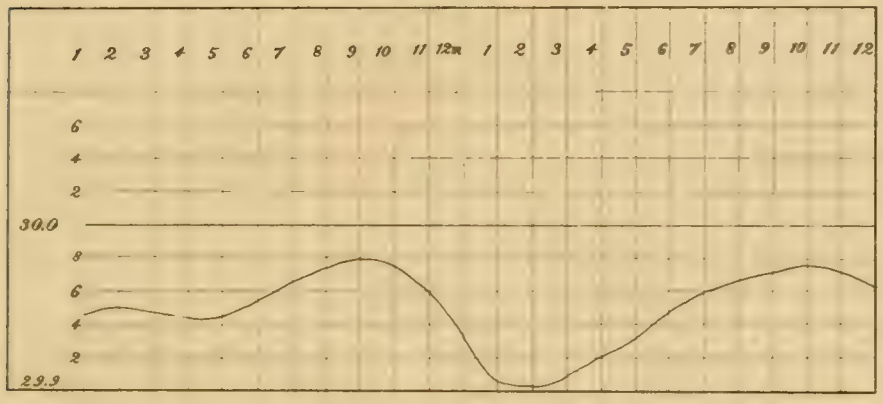
Showing hourly means of barometer during a portion of the year.

第十八圖

均ノ圖 各時觀測平 月中晴雨計 十二ノ四ケ 三年三六九 十年明治十 二千五百四

December.

十二月



Mean of Four Months.

四ケ月ノ平均圖

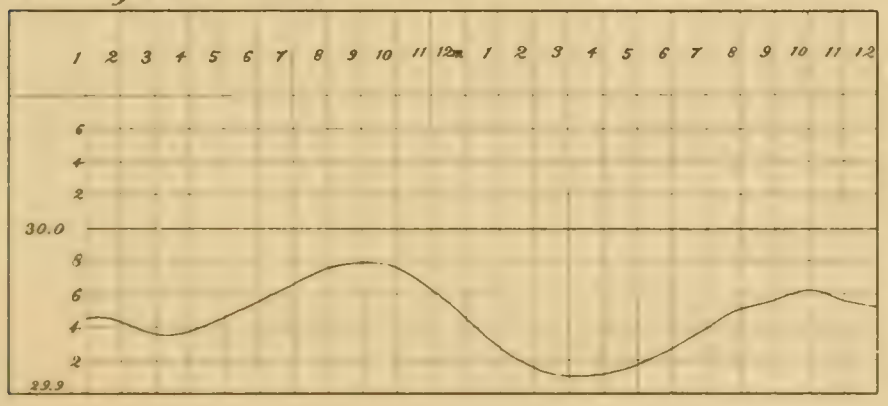
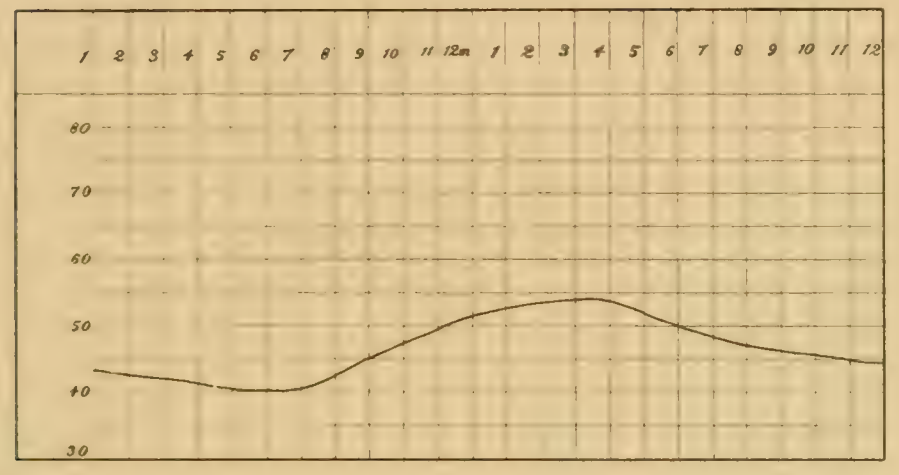


Chart No. 19.

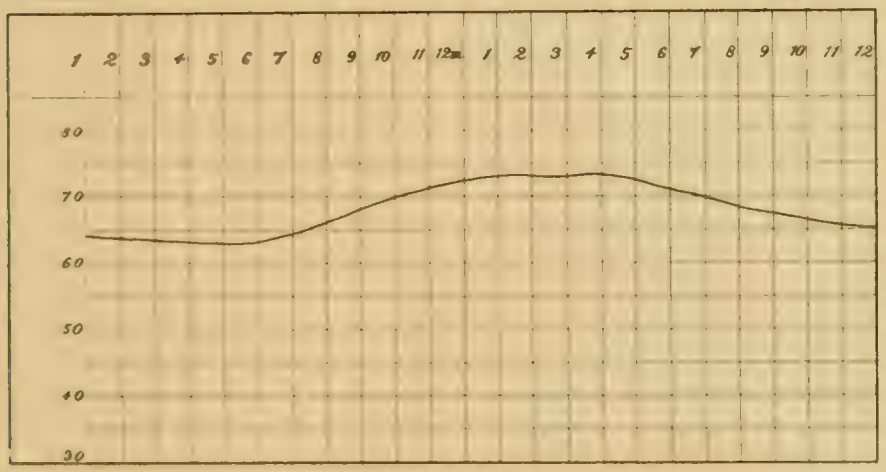
Showing hourly means of temperature during a portion of the year.

第十九回
十年(明治十)三月
二千五百四
十ヶ月中寒暖計
十二ノ四九
三六
各時觀測平
均ノ圖

March. 三月



June. 六月



September. 九月

Chart N.º 19.

Showing hourly means of temperature during a portion of the year.

第十九圖

二千五百四

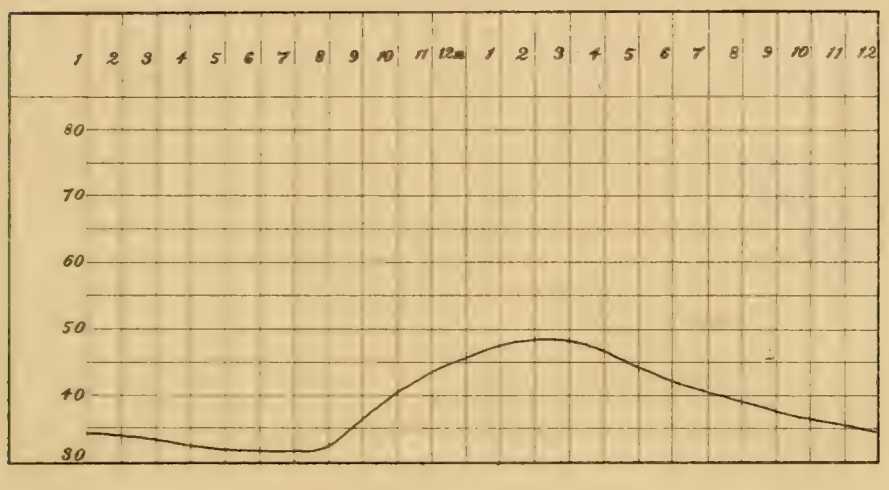
明治十年

三年
三六九

十二ノ四ヶ月中寒暖計各時觀測平均ノ圖

December.

十二月



Mean of Four Months.

四ヶ月ノ平均圖

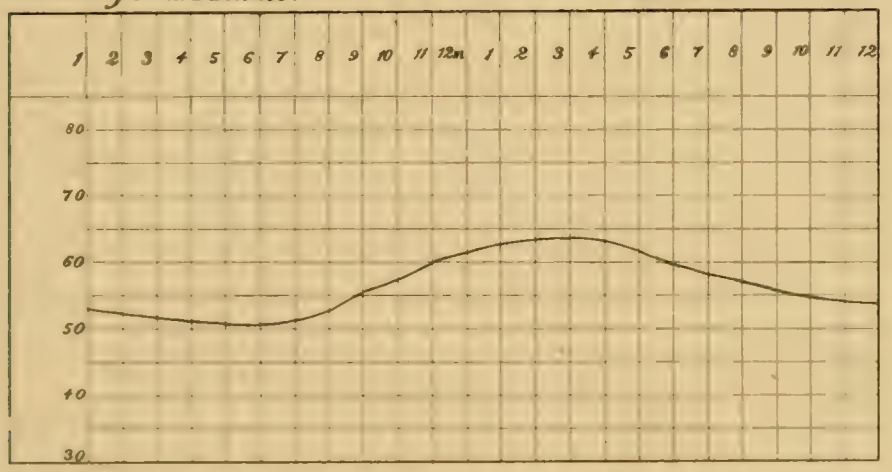


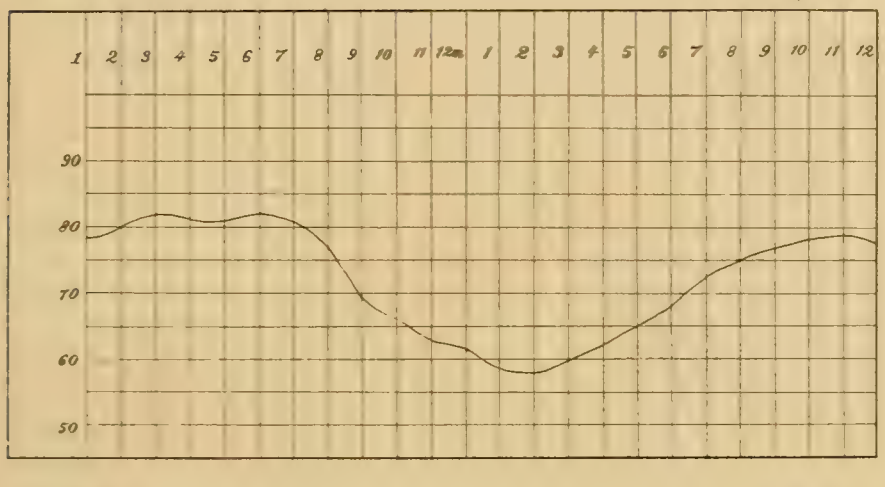
Chart N°. 20

Showing hourly means of percentage of humidity during a portion of the year.

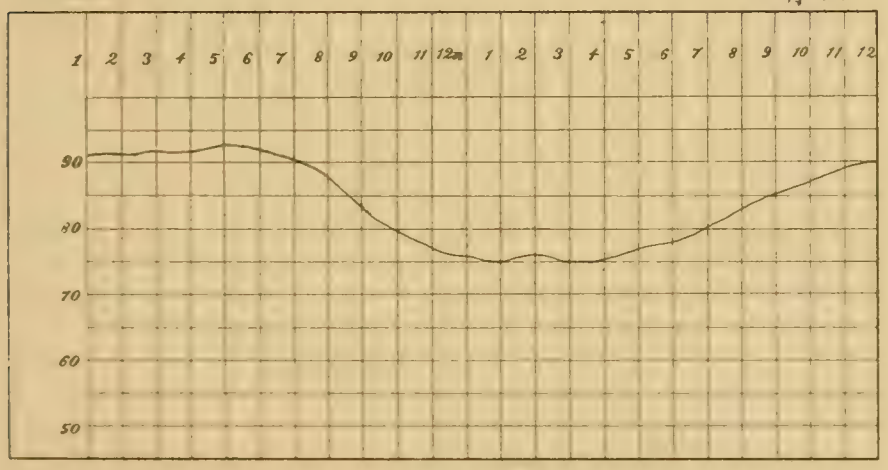
第二十二圖

二千五百四 明治十年 三六九 三年 十二ノ四ヶ月中水氣比較量各時觀測ノ平均者

March. 三月



June. 六月



September. 九月

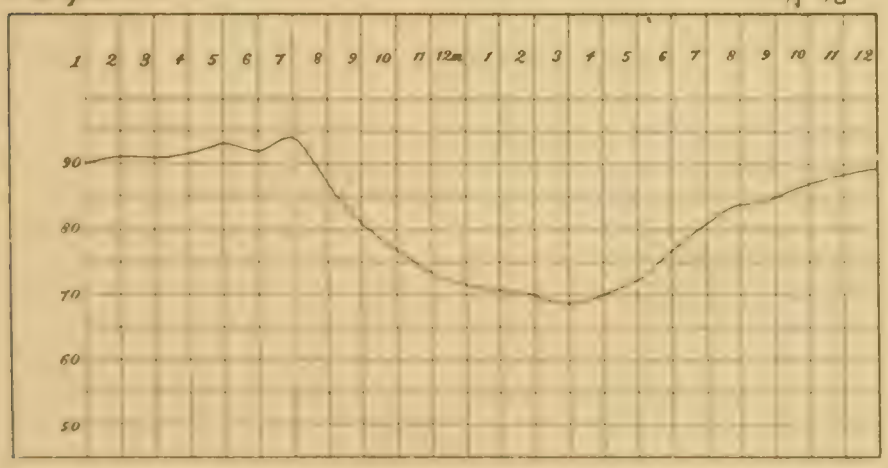


Chart No. 20

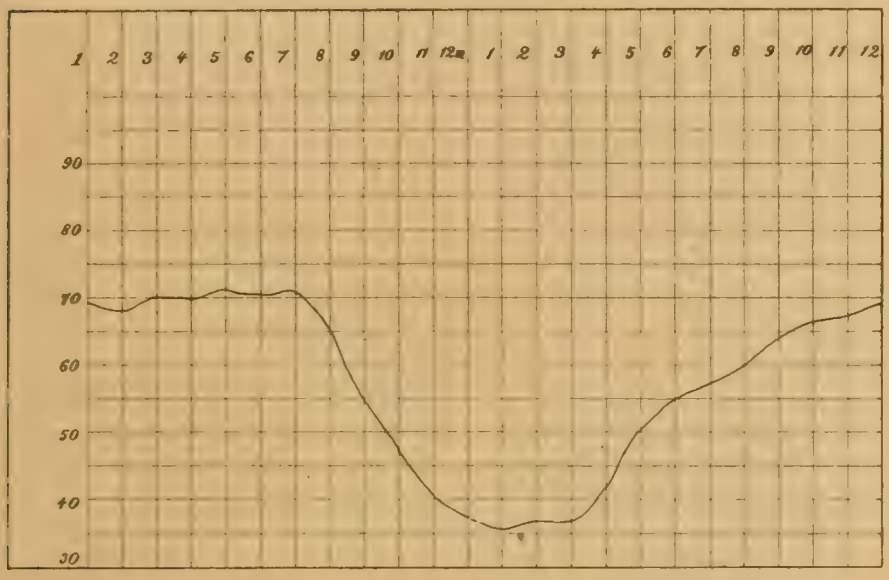
Showing hourly means of percentage of humidity during a portion of the year.

第二十圖。

二十五百四
十年(明治十)三年(三六九)
十二ノ四ヶ月中水氣比較量各時觀測ノ平均百

December.

十二月



Mean of Four Months.

四ヶ月ノ平均百

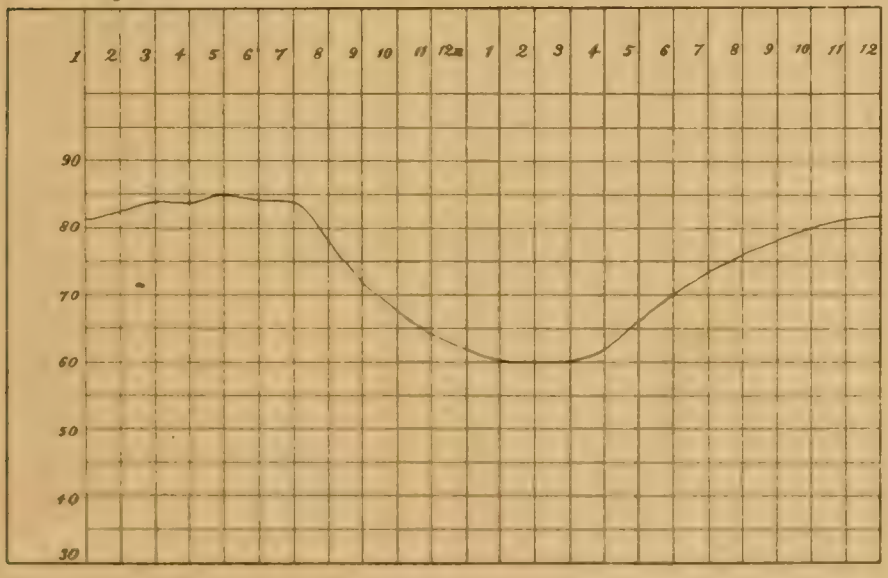
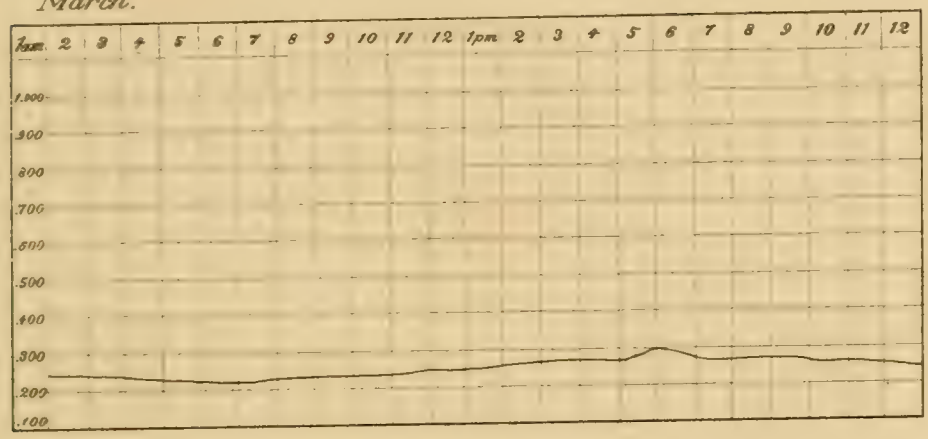


Chart No. 21

Showing hourly means of the force of vapor during a portion of the year.

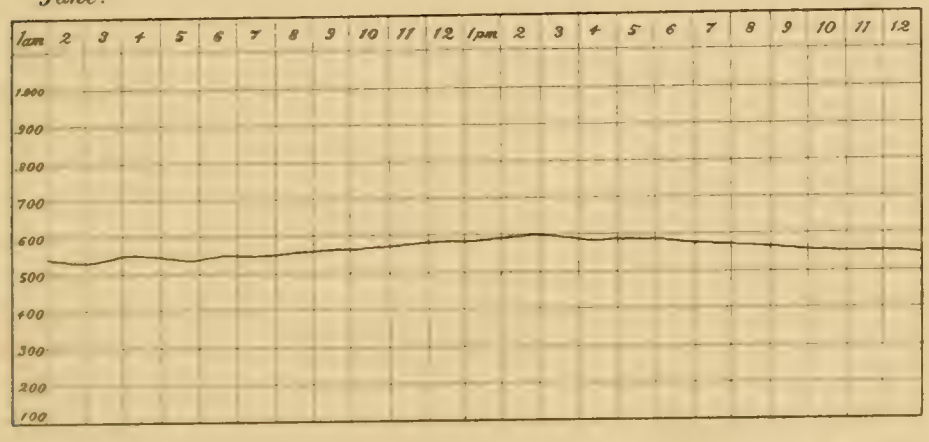
二千五百四
第十年明治十三年二月中各時観測水氣力ノ平均高
十二ノ四ケ
三六九

March.



六月

June.



九月

September.

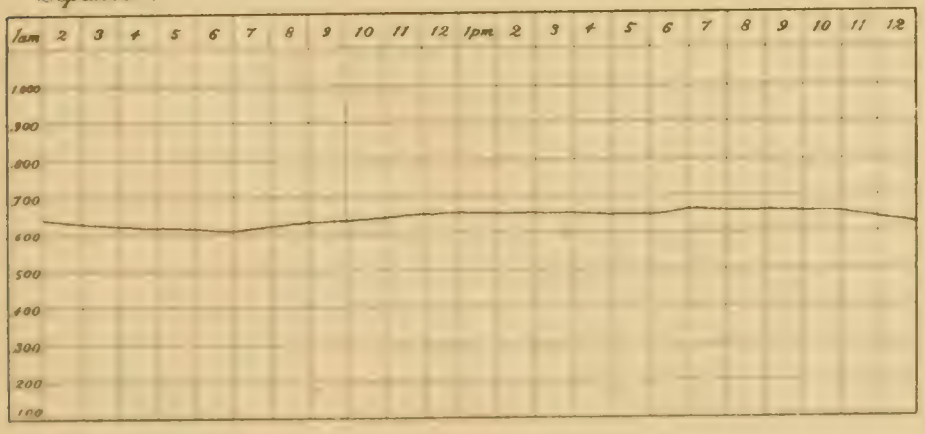


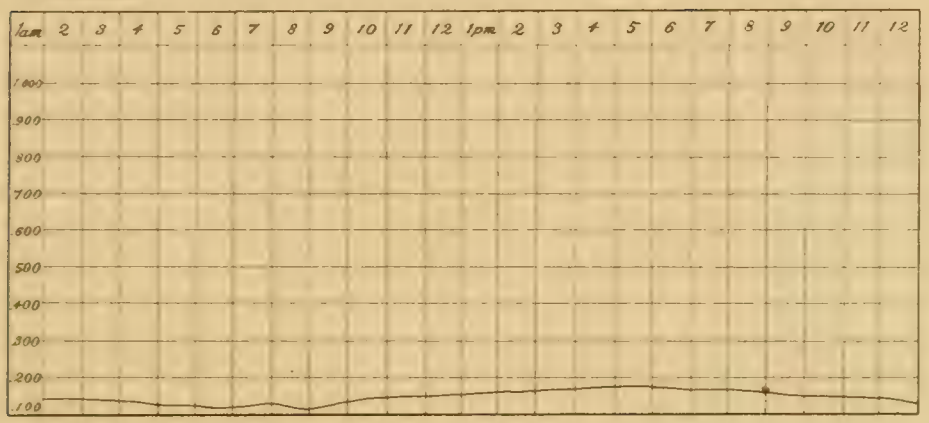
Chart No. 21

Showing hourly means of the force of vapor during a portion of the year.

第十年明治十二月中各時觀測水氣力ノ平均高

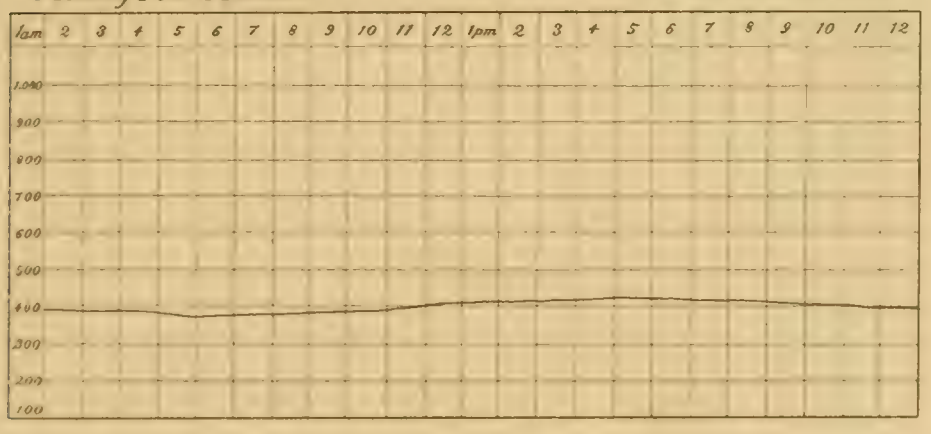
二千五百四十三年三六九ノ四ヶ月ノ平均高

December.



Mean of Four Months.

四ヶ月ノ平均高



MAGNETIC EXPERIMENTS.

There is no magnetic apparatus at present in the equipment of the observatory, nor does the physical laboratory of the university possess any of sufficient delicacy for making accurate magnetic measurements. During June and July 1880, Mr. Fujisawa, a special student in physics in the University, made a series of observations with the aid of such appliances as could be obtained, for the purpose of determining the horizontal component of magnetism at Tokio, with a view to making a comparison between the result and a similar series upon the summit of Fujinoyama. Although pretending to no great degree of accuracy the results are, perhaps, of sufficient interest to justify their publication in this report. From a report furnished by Mr. Fujisawa the following brief account of the experiments is taken.

Two magnets were used in the determination. The first (A) was 12 cm. in length, rectangular in section and weighed 68.83 grammes. The second (B) was 10 cm. in length, rectangular in section and weighed 57.58 grammes. In the determination of the horizontal component of magnetism at Tokio the ordinary method was pursued, the operations consisting in determining the period of vibration and the deflection from the magnetic meridian of another magnet placed at a measured distance. The time of a single vibration was determined by making a chronographic record of the transits of a point upon the end of the magnet across the vertical wires of a telescope placed at a distance of about 5 metres from the magnet. In this way the period of vibration of the magnet could be obtained to a degree of accuracy considerably exceeding that attainable in the other factors of the determination. The moment of inertia of the magnet was determined from its figure, its symmetry being such as to render that method sufficiently accurate. In the determination of the horizontal component magnet (A) was used; no deflection measurements were made with the other.

The following is one series of the results of observations for the period of this magnet; the time throughout is in sidereal seconds and the location for this series was in the physical laboratory of the University at Tokio.

July 1	Time of vibration
	10.6202
	10.6260
	10.6262
	10.6206
	10.6206
mean.....	10.6227

These, with other results, were combined with the results of deflection observations, the latter, owing to the imperfect nature of the apparatus, being more irregular. The mean of five complete determinations gave for the horizontal component;

$$H = .2953$$

the units employed being the cm, gramme and second.

Another series of three complete determinations gave as a mean;

$$H = .3012$$

And the mean of all gives—

$$H = .2975$$

Since these observations were completed I have been fortunate in being able, to secure the results of two other determinations of the horizontal component of the earth's magnetism, made in this vicinity and with appliances which are, in the main, far more perfect than those which Mr. Fujisawa was obliged to depend upon. For one of these I am indebted to the kindness of Commander Sampson U. S. N., who made a series of observations during the past summer in the yard of the U. S. Consulate at Yokohama. As determined by Commander Sampson the value is;

$$H = .29592$$

The other is to be found in a memoir recently published by Herr Otto Schütt of the Geological Survey who made a determination in Tokio, also during the past summer. The value there given is;

$$H = .30742$$

It will thus be seen that the value found by Mr. Fujisawa lies between these two determinations and it may probably be regarded as not far from the truth.

In August both of the magnets, (A), and (B), were carried to the summit of Fujinoyama and were vibrated there by Mr. Fujisawa, the period being determined in the same manner as in Tokio. It was necessary to carry on the magnetic experiments in the same small hut on the summit of the mountain in which the instruments for the gravitation determination were mounted and as the Chronograph was almost constantly in use in connection with the latter, it was found to be impossible to make more than two complete series of vibrations with each magnet. As soon as possible, after the return of the party and the instruments to Tokio, the magnets were again vibrated in order to ascertain what change, if any, had occurred in their magnetic condition during their absence.

The following are the mean results at different times and places.

	Date	Place	Time of vibration
(A)	July 1	Tokio	10.628
	August 5	Summit of Fujinoyama	10.903
	August 21 and 22	Tokio	10.648
(B)	July 6	Tokio	9.531
	August 5	Summit of Fujinoyama	9.827
	August 24	Tokio	9.570

It therefore appears probable that the intensity of magnetization had slightly diminished in both magnets and that the amount of this diminution was somewhat greater in (B) than in (A). If the mean of the times of vibration before and after the ascent of the mountain be accepted as the true periods, the results will appear as follows:

(A)	at Tokio	10.635
	on the mountain	10.903
(B)	at Tokio	9.551
	on the mountain	9.827

The relative intensities of the two magnetic fields being inversely as the squares of the times of vibration of the same magnet, it follows that the value of H on the summit of the mountain compared with that at Tokio will be;

from (A)	.951
,, (B)	.945
mean	.948

While these two magnets agree well in showing that the horizontal intensity is about five per cent less on the summit of the mountain than it is in Tokio, yet it must be remembered that the magnets were vibrated in the same place and under the same circumstances upon the summit. An examination of the loose fragments of lava found upon the summit reveals the fact that nearly, if not quite, all of them are slightly magnetic. It is therefore highly probable that results differing materially from those given above might have been obtained, had the location of the vibrating magnet been changed. Unfortunately it was impossible, in the few days during which the party remained upon the summit, to make suitable arrangements for repeating the vibrations at different points but it is hoped that a complete magnetic survey of the mountain may be undertaken in the near future.

THE HEIGHT OF FUJINOYAMA.

BY PROFESSOR W. S. CHAPLIN.

I. The following are the principal measurements which have been made of the height of Fujinoyama.

1	4322 metres	Alcock
2	3987	Fagan
3	3266	Williams
4	3518	Lépissier
5	3729	Knipping (first calculation)
6	3829	,, (second ,,)
7	3769	Stewart
8	3772	Fenton
9	3768	Favre-Brandt
10	3823	Nakamura & Wada.
11	3793	Siebold

II. The measurements from which Mr. Knipping has calculated the height were made, under his direction, by students of Kaisei Gakko (now Tokio Dai Gaku). The observations were taken at the tenth station on the mountain, and at Numadzu, a town on the sea-coast distant about 15 miles in a direction S. 30°. E. from the station on the mountain. Observations were made five times daily, at 7 and 10 in the forenoon and at 2, 4 and 9 in the afternoon for fifteen days, and each included a reading of the barometer, the thermometers and the psychrometer. For the first seven observations on the mountain no simultaneous observations were taken at Numadzu, so the observations on the mountain were compared with simultaneous ones taken at Tokio. Mr. Knipping says that the observers were skilful and that their work may be relied on.

Two calculations have been made to find the height from these data. The result of the first calculation is found on page 7 of the 3d Heft of the Mittheilungen der Deutschen Gesellschaft fuer Natur und Voelkerkunde Ostasiens. In making the calculation Mr. Knipping has used an approximate formula. proposed by Ruhlmann for use in Central Europe. His results are

7 A.M.	10 A.M.	2 P.M.	4 P.M.	9 P.M.
3731 metres	3775	3784	3769	3726

He has then taken a mean of the results at 7 A.M. and 9 P.M., as advised in Mueller's Physics, and found 3729 metres as the final result.

The second calculation was made with Bauernfeind's formula, using the psychrometric observations, which had not been used before, and which unfortunately

have not been published. He thus found as a mean of the observations at 10 A.M. and 4 P.M. (which are the best hours for measuring heights at that time of the year according to Bauernfeind) 3829 metres, and as a mean of those at 7 A. M. and 9 P.M., 3780 metres. An account of this calculation may be found in a paper by Mr. Knipping read before the Deutsche Gesellschaft &c. July 8th 1876. As Mr. Knipping gives no details of this second calculation, I have had the calculations made again, using as there were no psychrometric records the formula given in Guyot's tables and there credited to Delcros. The results are as follows:—

Date	7 A.m.	10 A.m.	2 P.m.	4 P.m.	9 P.m.
1873 July 27			3759	3742	3685
28	3680	3742	3764	3730	3686
29	3693	3738	3753	3754	3692
30	3704	3794	3759	3760	3706
31	3687	3725	3730	3774	3709
Aug. 1	3690	3743	3759	3723	3684
2	3677	3733	3749	3732	3694
3	3698	3733	3741	3712	3666
4	3691	3740	3742	3711	3690
5	3706	3733	3734	3735	3690
6	3731	3747	3756	3741	3697
7	3694	3756	3782	3756	3700
8	3706	3749	3785	3728	3679
9	3702	3747	3763	3727	3660
10	3656	3724	3717	3718	3643
Sum	52715	52404	56293	56048	55281
Mean	3765	3743	3753	3736	3685

To these must be added the height of the summit of the mountain above the tenth station, which is taken as 61 metres, and the height of the lower barometer above the sea-level, 10 metres; making the heights

3836 3814 3824 3807 3756

III. Mr. Stewart measured the height of Fujinoyama in 1874, using an omnimeter. He started from the summit and measured to the sea-level at

Numadzu, using 97 stations. Unfortunately he has not published any detailed account of the measurement. I am indebted for the facts which I give to a paper by Mr. Knipping in the 11th Heft of the Mittheilungen der Deutschen Gesellschaft &c. Mr. Stewart found a result of 12364 ft. (3768 metres) and estimated his probable error at 20 ft.

From my own examination of another omnimeter I am lead to believe that Mr. Stewart's estimate of the probable error is too small; in fact, I believe that if the instrument were used with ordinary care, the probable error would be nearer 50 ft. than 20 ft.; yet, in the absence of a detailed account of the measurement, it is only possible to guess at Mr. Stewart's error.

IV. Messrs. K. Nakamura and Y. Wada of the Surveying Bureau accompanied Prof. Mendenhall's party to the summit of Fujinoyama in the summer of 1880, and took barometric observations for determining the height of the mountain. The lower station was at Hara, at a distance of about 13 miles in a direction S. 12° E. from the summit, and at a height of 3 ft. above the sea-level. Their observations were taken hourly from 6 A.M. to 6 P.M. during two days, and included observations on the humidity of the air. After the completion of the work, as well as before leaving Tokio, the instruments used were all compared with standard instruments in Tokio, and the proper corrections for instrumental error were applied to the observations.

Messrs. Nakamura and Wada have given their observations and the result of their calculations of the height in the Echo du Japon, October 16th 1880. They have used Williamson's formula and tables, and have found as the mean of all the results 3823 metres.

Mr. Nojiri has recalculated the height from data furnished by Messrs. Nakamura and Wada, and obtained the following results in feet;—

6 A.M.	7 A.M.	8 A.M.	9 A.M.	10 A.M.	11 A.M.	12 M.
12311	12377	12532	12593	12608	12577	12608

1 P.M.	2 P.M.	3 P.M.	4 P.M.	5 P.M.	6 P.M.
12636	12591	12602	12630	12555	12480

The mean of these numbers is 12515 or 3812 metres. The difference between this result and that of Messrs. Nakamura and Wada arises from the fact that in the two calculations different tables for atmospheric humidity have been used.

V. The other measurements given in the table have been made, some of them with aneroid barometers, some by comparing the height of the barometric column on the mountain with the mean height of the barometer at the sea-level; and each of them depends upon a single observation. They are therefore of little weight compared with an extensive set of simultaneous observations with mercurial barometers.

VI. An examination of the individual results in either Mr. Knipping's, or Messrs. Nakamura and Wada's calculations will show that for an accurate measurement but little reliance can be placed on the barometer, variations of 50 metres from the average in either of them not being uncommon.

It has been found from long series of hourly and simultaneous observations, that the heights calculated by any of the ordinary formulæ from these observations are subject to several fluctuations. Generally, a height determined in summer is greater than when determined in winter; and greater in the daytime than in the night. The height thus follows roughly the variations in the barometric column, but not in such a way that we are able to find the time when the formula will give the mean height, when we know the time at which the barometric column is at its mean height. As both the sets of observations were made in the daytime and in summer we can say that the heights determined from these data are probably too great, but we can not say how much too great.

VII. Mr. Futami of the Surveying Bureau has kindly furnished me with data from which to calculate the height of the mountain trigonometrically. His observations of altitude were taken at three of the stations of the Geodetical Survey, one at Kanozan east of Tokio Bay, another at Amagisan in Idzu, and the third at Tanzawayama near Oyama. The instrument used was a theodolite reading by two verniers to 5″; the barometer and thermometer were read at every observation. I have used only the observations taken at Kanozan and Tanzawayama.

The height of Kanozan was found by levelling from the sea-shore to be 355.2 metres; and the instrument was 1.6 metres above the ground.

In calculating the height of Tanzawayama and Fujinoyama I have used Bauernfeind's formula, which may be found in his Elemente der Vermessungskunde Vol. 2, page 281, or in the U. S. Coast Survey Report for 1870 page 160.

The results were as follows

	T. above K.	K. below T.	F. above K.	F. above T.
	1222.7 m.	1198.2		2218.
	1227.5	1208.8		2217
	1218.5	1210.8	3439.6	2217
	1225.5	1202.5	3441	
	1214.2			
Sums	6108.4	4820.3	6880.6	6652
Average	1221.7	1205.1	3440.3	2217.

T above K = 1213.4

To get the height of Fujinoyama we then add

Height of Kanozan	355.2	
„ „ instrument	1.6	
F above K	3440.3	
	3797.1	metres;
or Height of Kanozan	355.2	
„ „ instrument	1.6	
T above K	1213.4	
F above T	2217.	
	3787.2	metres

The mean of these results is 3792 metres, which I am convinced is more nearly correct than any other of the results. It falls between the measurement of Mr. Stewart and those of Messrs. Nakamura and Wada and Mr. Knipping. The height will probably be determined soon by the Surveying Bureau, when we may expect to know it with great exactness.

Map showing Relative Position of Tokio. Fuji-no yama. Kano-zan. Amagi-san and Tanzawa-yama.

富士丹沢
天城鹿野
ノ諸山東
京近傍ノ
略圖

METEOROLOGICAL OBSERVATIONS ON FUJINOYAMA.

To Mr. R. Fujisawa, special student in Physics in the University, I am indebted for a carefully prepared report of the meteorological observations made by the party visiting the mountain in August 1880, the work of which has been already referred to in this volume. From this report I have selected the following observations and results which will doubtless be of considerable interest to those who are more or less familiar with the mountain as well as to all who are interested in the meteorology of elevated points.

The ascent was made by what is known as the Eastern or Subashiri route. A mountain Barometer (mercurial) was carried by the party and observations were made at different points during the ascent. Upon this route there are ten "stations" or stopping places, the last being at the summit. The following table gives the height of several of these stations above the sea, as deduced from the barometric observations. It will be remembered, of course, that they only pretend to be rough approximations as they are based upon a single observation at each point, the barometric height at the sea level having been assumed to be 30 inches. They may, however, prove to be interesting and useful to persons making the ascent of the mountain in the future. The numbers given represent the vertical height in feet between the various stations at which readings were made.

Sea level	0
Subashiri	2877
Mumagayeshi	2167
Chiujikiba	1615
Second Station	1240
Fifth „	1340
Eighth „	2113
Tenth „ (summit)	1140

A number of hypsometric observations were made during the stay upon the summit. The instrument used included a Fahrenheit thermometer reading to 212°. A careful test of the thermometer in the physical laboratory of the University did not indicate a greater error than one hundredth of a degree at that point. Barometric readings were taken at the same time, the results of which are to be found in the following table. In the fourth column will also be found the corresponding calculated temperature deduced by interpolation from Regnault's tables. The barometric readings are given in inches, after having been reduced to the freezing point. The first observation, that made on the afternoon

of August 3rd., was made with a centigrade thermometer. It will be observed that there is a nearly constant difference of about four tenths of a degree Fahrenheit between the observed and calculated temperatures.

Date		Barometer	Hypsometer	Calculated.
August 3	3 p.m.	19.350	88°.4 C	88°.2 C
,, 4	1 p.m.	19.363	190°.45	190°.86
,, ,,	3 p.m.	19.360	190°.50	190°.86
,, ,,	5 p.m.	19.357	190°.43	190°.85
,, 5	6 a.m.	19.377	190°.45	190°.90
,, ,,	8 a.m.	19.377	190°.50	190°.90
,, ,,	1 p.m.	19.366	190°.50	190°.87
,, ,,	2 p.m.	19.358	190°.43	190°.85
,, ,,	4 p.m.	19.352	190°.40	190°.84
,, ,,	7.30 p.m.	19.352	190°.40	190°.84
,, ,,	9 p.m.	19.350	190°.40	190°.83

The following table contains the meteorological observations made during the ascent and upon the summit.

Date	Barometric Pressure reduced to 32°F	Temperature (F)	Relative Humidity %	Weather	Station
August 1880					
1st					
6h 30′ P.M.	27.310				Subashiri
7h 30′ P.M.	27.305				..
9h 0′ P.M.	27.303				,,
2nd					
5h 0′ P.M.	27.293	—	—	fair	Subashiri
6h 30′ A.M.	25.546	—	—	,,	Mumagayeshi
8h 30′ A.M.	23.880	71	78	cloudy	Chiujikiba
10h 8′ A.M.	22.849	64.8	80	rainy	2nd Station
11h 40′ A.M.	21.755	61.5	84	cloudy	5th Station
P.M.	20.177	44.9	85	clear	8th Station
3rd					
Sun rise		42.0	88	clear	8th Station
7h 30′ A.M.	19.303	41.6	95	fair	Kakema The Summit
9h 0′ A.M.	19.342	52.5	83	fair	Tent
12h 0′	19.350	61.5	87	fair	,,
1h 45′ P.M.	19.342	57.8	—	fair	,,
2h 40′ P.M.	19.204	—	—	fair	Kengamine
6h 0′ P.M.	19.341	50.4	66	fine	Tent
9h 0′ P.M.	19.373	—	—	fine	,,
4th					
5h A.M.	19.351	38	—	fine	Tent
6h A.M.	19.351	41.0	93	,,	,,
7h A.M.	19.372	41.0	81	,,	,,
8h A.M.	19.370	46.0	81	,,	,,
9h A.M.	19.375	51.2	69	,,	,,
10h A.M.	19.368	52.5	83	,,	,,
11h A.M.	19.367	55.2	61	,,	,,
12h	19.364	55.6	57	,,	,,
1h P.M.	19.363	57.1	51	,,	,,
2h P.M.	19.361	62.6	41	,,	,,
8h P.M.	19.360	57.6	51	,,	,,

Date	Barometric Pressure reduced to 32°F	Temperature (F)	Relative Humidity %	Weather	Station
August 1880					
4th					
4h P.M.	19.355	62.6	40	fine windy	Tent
5h P.M.	19.357	50.2	64	,,	,,
6h P.M.	19.371	45.6	64	,,	,,
5th					
6h A.M.	19.377	37.3	76	fine windy	Tent
7h ,,	19.363	39.3	71	,,	Temple
8h ,,	19.377	39.9	91	,,	,,
9h ,,	19.379	40.4	89	fair	,,
10h ,,	19.366	41.9	89	fine	,,
11h ,,	19.364	41.1	90	,,	,,
12h	19.360	41.8	90	,,	,,
1h P.M.	19.366	45.1	81	,,	,,
2h ,,	19.358	45.1	83	,,	,,
3h ,,	19.358	46.3	84	,,	,,
4h ,,	19.352	45.0	85	,,	,,
5h ,,	19.351	44.5	85	fine windy	,,
6h ,,	19.352	42.8	88	,,	,,
7h ,,	19.359	42.6	88	fair heavy wind	,,
8h ,,	19.358	40.7	86	fair windy	,,
9h ,,	19.357	39.9	85	fair heavy wind	,,
10h ,,	19.353	39.1	84	,,	,,

A minimum thermometer was exposed during the stay upon the summit with the following results;—

Night of 3rd and 4th..... 31°.4
,, ,, 4th and 5th..... 34°.2
,, ,, 5th and 6th..... 33°.0

A maximum thermometer was exposed to the sun on the fourth and fifth and the temperatures reached were as follows;—

On the 4th..... 90°.0
,, ,, 5th..... 82°.5

On the afternoon of the 6th Mr. Fujisawa and Mr. Tanakadate descended to the bottom of the crater and made three barometric readings at different points which were as follows;—

Northern part.....	19.775
Southern „	19.758
„ „	19.777

As before stated, Messrs. Nakamura and Wada accompanied the party to Fujinoyama and maintained, during two or three days a series of simultaneous Barometric and Hygrometric observations upon the summit and at the sea-level. These observations, reduced and corrected, they have kindly furnished for publication in this report in connection with those made by others of the party. They are given in the following tables.

BAROMETRIC AND HYGROMETRIC OBSERVATIONS MADE ON THE SUMMIT OF FUJINOYAMA AND AT THE SEA-LEVEL BY MESSRS. NAKAMURA AND WADA.

August 1880.		Barometer.					
		Reading (English inches).		Attached thermometer (Fah. degrees).		Corrected for index error, capillary action and to Freezing point.	
Day.	Hour.	Lower Station.	Upper Station.	Lower Station.	Upper Station.	Lower Station.	Upper Station.
3	6 AM	29.957	..	78.3	..	29.854	..
3	7 AM	965	..	79.8	..	857	..
3	8 AM	973	..	81.3	..	860	..
3	9 AM	982	..	82.9	..	866	..
3	10 AM	976	..	82.9	..	860	..
3	11 AM	965	..	83.8	..	846	..
3	Noon	965	19.390	85.6	58.8	841	19.350
3	1 PM	957	..	86.1	..	833	..
3	2 PM	949	..	86.5	..	822	..
3	3 PM	952	..	88.0	..	823	..
3	4 PM	961	..	91.8	..	821	..
3	5 PM	969	..	88.7	..	837	..
3	6 PM	965	19.374	81.9	51.2	852	19.341
4	6 AM	30.000	19.376	70.7	44.8	916	19.351
4	7 AM	035	410	78.3	52.8	932	372
4	8 AM	035	416	78.3	58.0	932	370
4	9 AM	047	420	80.1	57.0	939	375
4	10 AM	051	420	81.1	60.8	940	368
4	11 AM	054	419	83.7	60.8	938	367
4	Noon	057	417	86.2	62.3	933	364
4	1 PM	043	419	86.9	63.7	916	363
4	2 PM	031	419	86.9	65.0	904	361
4	3 PM	043	415	87.8	62.8	914	360
4	4 PM	033	409	85.0	65.5	912	355
4	5 PM	024	398	83.8	55.0	905	357
4	6 PM	028	398	82.4	45.8	915	371
5	6 AM	031	390	68.7	39.5	952	377
5	7 AM	047	385	71.5	43.5	960	363
5	8 AM	075	400	79.5	44.0	967	377
5	9 AM	071	394	82.8	46.0	955	379
5	10 AM	075	396	84.0	48.6	956	366
5	11 AM	071	398	86.9	51.3	944	364
5	Noon	071	400	88.5	54.0	939	360
5	1 PM	067	402	91.0	52.0	930	366
5	2 PM	043	394	82.4	52.1	930	358
5	3 PM	035	388	80.4	48.0	927	358
5	4 PM	030	381	81.8	47.5	917	352
5	5 PM	026	376	83.1	45.0	910	351
5	6 PM	026	372	82.4	42.1	913	352
Means	6 AM	29.996	19.383	72.6	42.2	29.907	19.364
	7 AM	30.016	398	76.5	48.2	916	368
	8 AM	028	408	79.7	51.0	920	374
	9 AM	036	407	81.9	51.5	920	377
	10 AM	034	408	82.7	54.7	919	367
	11 AM	030	409	84.8	56.1	910	366
	Noon	031	409	86.8	58.2	905	362
	1 PM	022	411	88.0	57.9	895	365
	2 PM	008	407	85.3	58.6	885	360
	3 PM	010	402	85.4	55.4	888	359
	4 PM	008	395	86.2	56.5	880	354
	5 PM	006	387	85.2	50.0	887	354
	6 PM	006	385	82.2	44.0	897	362

BAROMETRIC AND HYGROMETRIC OBSERVATIONS MADE ON THE SUMMIT OF FUJINOYAMA AND AT THE SEA-LEVEL BY MESSRS. NAKAMURA AND WADA.

August 1880.		Hygrometer.					
		Dry bulb thermometer (Fah. degrees).		Wet bulb thermometer (Fah. degrees).		Temperature of dew point (Fah. degrees).	
Day.	Hour.	Lower Station.	Upper Station.	Lower Station.	Upper Station.	Lower Station.	Upper Station.
3	6 AM	78.8	,,	76.9	,,	75.6	,,
3	7 AM	79.6	,,	77.0	,,	75.1	,,
3	8 AM	80.4	,,	77.1	,,	74.6	,,
3	9 AM	81.8	,,	77.2	,,	74.0	,,
3	10 AM	82.7	,,	77.5	,,	73.9	,,
3	11 AM	83.2	,,	78.0	,,	74.4	,,
3	Noon	84.9	61.5	79.0	59.5	74.9	58.5
3	1 PM	85.4	,,	79.4	,,	75.2	,,
3	2 PM	85.9	,,	79.7	,,	75.4	,,
3	3 PM	87.5	,,	81.0	,,	77.1	,,
3	4 PM	87.9	,,	81.5	,,	76.7	,,
3	5 PM	84.8	,,	79.7	,,	76.1	,,
3	6 PM	82.6	50.4	78.8	44.5	76.1	39.5
4	6 AM	72.0	42.0	70.3	41.0	79.1	40.1
4	7 AM	76.9	44.0	73.0	41.1	70.3	38.4
4	8 AM	79.0	46.0	74.8	43.1	71.9	40.6
4	9 AM	80.2	51.1	76.0	45.6	73.1	41.1
4	10 AM	81.7	51.5	75.5	48.5	71.2	46.4
4	11 AM	83.9	55.1	76.7	47.7	72.2	41.8
4	Noon	86.0	55.5	77.8	47.1	73.1	40.4
4	1 PM	86.5	57.0	78.2	47.1	73.2	39.0
4	2 PM	86.0	62.5	79.9	49.2	75.6	38.7
4	3 PM	88.0	57.5	81.2	47.5	77.1	39.5
4	4 PM	85.2	62.5	80.8	49.0	77.3	38.2
4	5 PM	84.5	50.1	80.5	44.0	77.7	38.6
4	6 PM	82.3	45.5	79.0	41.2	76.7	37.2
5	6 AM	74.2	37.2	72.9	34.5	72.0	30.3
5	7 AM	75.1	39.2	73.3	35.5	72.0	31.4
5	8 AM	79.2	39.8	75.5	38.6	72.9	37.5
5	9 AM	83.4	40.3	79.5	38.8	76.8	37.4
5	10 AM	85.0	40.8	79.5	39.3	75.7	37.9
5	11 AM	87.6	41.2	79.7	39.8	75.0	38.5
5	Noon	89.2	41.7	81.9	40.2	77.5	38.8
5	1 PM	91.5	45.0	83.1	42.0	79.7	39.3
5	2 PM	78.1	45.0	77.0	42.4	76.2	40.1
5	3 PM	81.2	46.3	78.1	43.8	75.9	41.7
5	4 PM	83.9	45.0	80.0	42.7	77.5	40.7
5	5 PM	86.5	44.4	81.9	42.1	79.1	40.1
5	6 PM	83.8	42.8	81.4	41.0	79.7	39.4
Means	6 AM	75.0	39.6	73.4	37.8	72.2	35.2
	7 AM	77.2	41.6	74.4	38.3	72.7	34.9
	8 AM	79.5	42.9	75.8	40.9	73.7	39.1
	9 AM	81.8	45.7	77.6	42.2	74.6	39.3
	10 AM	83.1	46.2	77.5	43.9	73.6	42.2
	11 AM	84.9	48.2	78.1	43.8	73.9	40.2
	Noon	86.7	48.6	79.6	43.5	75.2	39.6
	1 PM	87.8	51.0	80.2	44.6	76.0	39.2
	2 PM	83.3	53.8	78.8	45.8	75.7	39.1
	3 PM	85.6	51.9	80.1	45.7	76.7	40.6
	4 PM	85.6	53.8	80.8	45.9	77.2	39.5
	5 PM	85.3	47.3	80.7	43.1	77.6	39.1
	6 PM	82.9	44.2	79.7	41.1	77.5	38.3

FIRES IN TOKIO.

BY PROFESSOR K. YAMAGAWA.

In the City of Tokio, fires are so frequent and destructive, that they doubtless involve greater losses in the shape of property destroyed than all other causes combined. To one who has not resided in Tokio, it is difficult to conceive their magnitude and the devastation caused by them. It is not strange that residents of foreign countries, who have never been in Japan, can hardly credit the accounts of these conflagrations which are published; for in their own countries, houses are, in general, so much more substantial in their character, that they are not only less combustible, but the progress of a fire is thus made slow enough to render the task of extinction comparatively easy. With us, however, houses are generally wooden, and on windy days, when a fire is once started it is likely to grow, within a short space of time, to one of extensive magnitude and even with far better means of extinguishing fires, than we have at present, it would be almost impossible to arrest it until it dies away of itself on reaching the limits of the city, or by reason of the entire cessation of the wind. It is said, that in Tokio, the average age of a house is seven years, that is to say, the whole city is burned every seven years. The assertion is no doubt exagerated as regards to the greater portion of the city, but if we take the most populous parts such as Kanda and Nihonbashi wards, the above assertion is very approximately true. During the reign of the Tokugawa Shoguns, Tokio, then called Yedo, with double the present population, was the emporium of wealth of the whole of Japan; and any destruction of property was made good by the rest of the country, as fast as it occurred, so that not only were fires less dreaded than would be expected, but in some cases they were rather desired than otherwise. Paradoxical as it seems, conflagrations used to be called the "ornaments of the city." I cannot go into details to explain the complicated system of Feudalism that bore such strange fruit as this; suffice it to say that in old times the population was much larger than at present, and the people had less fear of fires, so that they occurred much more frequently before the late revolution, one of the results of which was the destruction of the feudal system, than at present. Below will be found a table of areas of houses burned each year since the revolution in 1868. The column of areas gives the space actually occupied by houses burned during each year and estimated in *tsubo*, one *tsubo* being about 6 feet square. The total area occupied by houses in Tokio at the present time, is 3,136,858 tsubo, so that the mean in the table is about 1½ % of the total area occupied by houses, and at this rate it will be about 66 years before the whole city is burned once. This, however, is a calculation based on the statistics of the period known to have been more free from fires than any other, so that this rate may or may not hold in the future. On the one hand the population is increasing very fast, which fact will make the probability of

Date.	Area.
1868	19,334
1869	40,936
1870	41,577
1871	28,280
1872	39,009
1873	73,230
1874	12,104
1875	20,824
1876	124,756
1877	37,289
1878	57,855
1879	103,213
1880	68,684
Total.	677,067
Mean.	52,082

fires greater, and on the other hand, the character of the building is being improved, and the system of fire-brigades is becoming more efficient. Whatever may be the frequency and extent of fires in future, at the present rate, the whole city is burned down every 66 years, and as this is based upon the experience of the last thirteen years, a period during which fires were less frequent than at any previous time, I think it is not at all exagerating to say that in former times, when fires were much more frequent, the districts in Tokio, where houses are built very closely together, and in which fires are very frequent, the average age of a house was about 7 years. The last winter was remarkable in the frequency and extent of fires. If we take the last four fires of considerable extent during the last winter, as exhibited in the subjoined table, the total number of houses (a house or number of houses or a part of a house occupied by a single family is counted as one house) burnt by these fires, of which only one can be called a great fire according to the meaning of the term used further on, is 26,200. The total number of houses in Tokio is something over 285,000 so that these four fires alone destroyed about one eleventh part of the city in about two months of the fire season. This will show that the assertion concerning the average age of a house in the most populous parts of the city is by no means impossible.

Date.	No. of houses burned each time.
1880—Dec. 30	2200
1881—Jan. 26	15500
,, —Feb. 11	7100
,, — ,, 21	1400
Total.	26200

The City of Tokio, formerly called Yedo, was founded by the first Shogun (the military ruler of Japan during the Feudal period) of the Tokugawa dynasty in 1590. The site of the city was a mere marshy plain with fishing villages scattered here and there, but being made the capital of the Shogun Government, it grew in size very rapidly, and in a few years, became a city of considerable size. It early became a victim of the flames for in less than 11 years after its foundation, namely in 1601, the record handed down says that the city of Yedo was burned entirely. Eighteen years after another great fire is recorded; and twenty-six years after the latter, the part of the city, where at present the Ginza street and others are found, was burnt, the fire spreading in a southern direction, burning some eight thousand houses. These three fires are the only ones recorded; the details, however are not known; hence they are not included in the following table. Table A contains nearly all fires of considerable magnitude that have occurred during the last 224 years, that is from 1657 to 1881.* From various records, written and printed, I have selected those fires, whose length is greater than 15 *cho* (one *cho* is about 360 feet) starting from

the origin of fire to the farthest point in the burnt district, and the length is measured by an ordinary scale on a good map of Tokio published by the Surveying Bureau of the Interior Dept., a process sufficiently accurate for this kind of work. I have obtained the direction of fires by measuring with a protractor the inclinations of straight lines to eight points of the compass; when the lines fall between two points, I take the nearest as the directions of the lines, and consequently the direction of fires. Table A gives in the first column the number, in the second the date,† in the third column, the directions measured as stated above, and the last column contains the magnitudes. In the accompanying map of Tokio, the straight lines used to determine the directions, and magnitudes are plotted, a number is attached to each so that it may be referred to Table A. A glance on the map will show to any one, that the greater number of fires travel from the directions N and NW; in fact two-thirds of the fires are from these two directions. Another point noticeable in the map is, that the lines seem to converge to the south-east corner of the city which is a necessary consequence of the local arrangement of the city together with the N and NW winds. Near the point, where the fire No. 17 begins, the moat is crossed by a bridge continuing the main street running from north to south. This bridge is called Nihonbashi, the "Japan bridge", whence all distances in the empire are taken. The region near the Nihonbashi, especially the part to the north of the bridge, is the most populous portion of the city and most frequently visited by fires, as is seen by the number of lines crossing each other in this district. The longest line in the map is No. 56, and by referring to Table A, we see that its length is 133 cho or about nine miles; this is perhaps the longest fire in the record. It occurred on April 1st 1772; the day was extremely windy, and at about noon, a fire originated in a temple in the south western limit of the city. It spread so rapidly that in less than 24 hours, it reached the northern limit of the city. While the fire was still raging, the wind shifted to W, and all that part of the city included between the river and the straight line in the map was almost entirely destroyed. The following may be regarded as the six most extensive fires that have raged in the city since its foundation; Nos. 1, 2 and 3 forming one group, Nos. 6, 7, 8 and 9 forming another, No. 15, No. 42, No. 56 and No. 69. In the first two instances, fires of considerable extent occurring very near to each other in time, they have been grouped together and regarded as one fire, although they are, in fact, entirely independent. In each of these, more than two-thirds of the city was burned. The first group is justly regarded as the most extensive. On March 2nd 1657, at about 2 P.M. a fire occurred in the north-west part of the city. The velocity of the wind was enormous:

* The magnitudes of fires are best measured by the areas of burnt district; but not having sufficient data further, I have taken the length as a measure.

† Months and days are reduced from lunar calendar to solar calendar for obvious reasons.

judging from the records and descriptions of the fire, I am inclined to think, that during most of the time of the fire it must have been more than 60 miles per hour. It travelled towards the south-east, and in less than 24 hours, it reached the sea in the eastern side of the river; next day, while this fire was still doing its work of destruction, another broke out at a point, about half a mile south-west of the origin of the first. The wind was still blowing with unabated fury, and after reducing the palace of the Shogun in the castle, and a countless number of magnificent houses belonging to the Feudal princes, to ashes, the fire ceased, having reached the sea. But before this terminated, another had begun about a mile south of the origin of the second, and it also reached the sea in the south-eastern part of the city. The number of persons killed by being burnt to death, drowned, crushed, etc. seems to have been something enormous; old chroniclers delight in putting down this number as 107,046., and whatever doubt we may have as to the numerical accuracy of this statement, it is certain that the number was great; the bodies being so numerous that identification was impossible, and all were carried to a large excavation made near the Rio-goku-bridge, and buried there. The temple Yekô-in, where the great wrestling matches are now held twice a year, was built then near the grave of so many unfortunates for the benefit of their souls. The second group of fires took place on March 13, 1668 originating in the western part of the city, and terminating in the sea. While the fire was still burning another broke out, although the latter was small the length not being greater than 21 *cho*. Three days afterward, a fire broke out in the western part of the city, and destroyed a district of the city 43 *cho* long, and two days after the latter, another occurred, so that in this group, although each one is not very extensive, the four together covered a great area. The third great fire took place on Oct. 9 1698 at about 10 in the morning, near the present site of the railway station and extended to the northern limit of the city. The fourth began in the south-western part and nearly reached the northern limit of the city; the fifth has been referred to above, and the sixth originating near the southern limit of the city reached the north east limit, taking place at about noon Apr. 22, 1806. This destroyed the best half of the city, and it is said, that more than 12 hundred people were killed in one way and another. Of these six, it must be noticed that three of them are from the NW and the other three are from the S and SW. In fact, these seem to be the directions to which the high winds are confined (by a high wind is here meant a wind whose velocity is greater than 20 miles per hour) and consequently the directions of great fires.

In Table B, all the fires, that I have been able to study, 93 in all, occurring during the last two hundred twenty four years, and each not shorter than 15 *cho*, are tabulated with reference to time and direction, so as to show the number of fires in a given direction in different months. In table C, will be found the total sum of the lengths of fires that occurred in different months from various directions. Looking at these tables, with reference to time we notice a remarkable

absence of fires during the months of July and August, but from September, they increase in number growing greater and greater until a maximum is reached in the month of March; then the number gradually decreases till it becomes zero in July. This fact is more strikingly shown in Chart A in which the upper broken line indicates the number of fires in different months, the scale of number of fires being on the upper half of the left edge of the chart. The chart tells its own story too well to need any comment. The lower broken line represents the number of miles of wind during each month, the scale of the number of miles being written on the right lower edge of the chart. The number of miles is the average from observations during the years 1879 and 1880, so that the broken line or the curve may not *exactly* represent the true average; I am, however, of opinion, that it is sufficiently near the true average for our purpose. In comparing these two curves, one is struck with a remarkable general similarity between the two, showing the obvious truth, that the wind is the main cause of great fires. In both these curves, a maximum occurs in the month of March. The fact that March is the windiest month in year, no doubt, makes the frequency of fires during that month the greatest. One important fact noticeable in the chart, is the remarkable difference between the two curves as regards the month of July, which can be explained by the following consideration: although winds are more frequent in July than in the adjacent months, as we have little need of fires during the hot summer months, the danger of a fire originating accidentally is greatly lessened and the probability of a great fire at this time is proportionately diminished. This is undoubtedly the cause of the difference between the two curves. The curves in Chart B, are very similar to those in Chart A; except that the lower curve is drawn so as to show the total number of high winds during the years 1879 & 1880 (in the chart, the heading ought to read "total number during 1879 & 1880" instead of "mean of 1879 & 1880)". In their general characteristics the two curves agree remarkably well except in the month of August, which can be explained by the same consideration as before. As an additional explanation of the absence of great fires during July, the lower curve in this chart shows a great depression for July indicating that there is a very small number of high winds during this month, and consequently a smaller probability of the occurrence of great fires. In Chart E, the horizontal straight lines are drawn so as to show the relative magnitudes of all the fires in Table A; in each, a line representing a fire is drawn so as to fall on a particular point in the month, representing the day of occurrence and here again lines are crowded together in the month of March. Charts C and D are very similar to Charts A and B; but instead of being referred to time they are referred to directions. With reference to directions, in Tables B and C, we see at a glance, that nearly all the fires have the directions N, NW, S and SW; and that those from the N and NW are the greatest in number. Referring to Chart C, we begin at E with no fire, one with SE, and S and SW have respectively 10 and 13. The curve falls to zero at W; then rises enormously at NW and attains a maxi-

mum at N, and then again falls at NE. The lower curve is a wind curve drawn by taking mean numbers of miles of wind during 1879 and 1880 from each direction. The general characters of the two curves are very similar, with a difference at the SW. In Chart D, the upper curve is the same as in Chart C, and the wind curve is drawn so as to show the mean number of high winds from various direction, the mean of 1879 and 1880 being taken. Again the two curves show a striking similarity with the same difference as in Chart C. In all the charts, it must be noticed, that when there is any difference between the fire and wind curves, it always occurs on the hot months, and it is believed that a sufficient explanation for this difference has already been given. Now the tables and charts discussed above establish beyond dispute: 1st the season of great fires begins in November, and after attaining a maximum frequency on March, ends on May, comprising a period of seven months, and 2nd the most fires move either from the N, or NW, or from the S or SW; and 3rd these results are not mere accidents, but are the necessary consequences of the local meteorology of Tokio.

I will conclude by referring briefly to the causes of fires, and to the loss of property which they occasion. The origin of fires may be traced to various causes but among them are two which seem to me of greater importance than others. The first is the use of kerosine oil, one of new introduction. This being an article but recently introduced the people are not accustomed to handle it, and the result is such carelessness, that undoubtedly a great many fires originate in this way. A number of determinations of the "flashing point" of samples of oil sold in Tokio have been made in the Physical Laboratory of the University. In nearly all, the temperature of *flashing point* was far lower than it ought to be. In some samples, it was as low as 96° F., and in none of them, was it higher than 120° F., the legal minimum in Great Britain, and in some States of the American Union. For the so called "safety oil", the temperature of the *flashing point* was considerably higher; in fact, in all samples examined, the temperature was above 120° F. It is evident that the attention of the authorities ought to be called to this point and proper restrictions placed upon its sale. The second important cause is incendiarism. There is much difficulty in obtaining an accurate estimate of the proportion of fires caused by incendiarism. The owner of the house, where a fire has originated, always shows a reluctance to give a true account of its origin; he tries to attribute it to a criminal design, whenever he can. Light as is the fine to an unwilling agent of others' losses, the moral effect on him is strong enough to make him conceal an accident, that happened in his own house. Hence often the police authority are unable to discover the real cause and the fire is classed in the catalogue as of unknown origin. But even allowing for this, fires of unknown origin are so numerous as to lead us to suspect that a great many of them have originated in a criminal design. The past season has been unsual in the number of incendiary fires, the rise of prices of necessaries doubtless having driven many to commit this crime and the police authority have done their utmost in the way of arresting criminals; next year will show, whether they have succeded or not.

According to the Fire Insurance Commission of the Treasury (through whose kindness, I obtained the table giving the areas of burnt houses for last 13 years) the average value of one tsubo (about six feet square) of a house is about 30 yen (a gold yen=about a dollar) and for the last 13 years, an average of 52,000 tsubo of houses has been burnt every year making the total annual loss 1,560,000 yen. This is an average of a period known to have been exceptionally free from fires; and besides, this includes nothing but houses. If we were to include all items of loss direct and indirect, it can not be less than 3,000,000 yen every year. The loss of houses, and other property by fire is a loss absolute in all senses, a loss not only to the city, but to the general community. If we can absolutely prevent fires by spending 3 million yen every year, it would be a gain to the country; but I think, a far smaller amount would be quite sufficient to organize a system of fire brigades, that would absolutely prevent any fires of great extent. If the people of Tokio were willing to spend $\frac{1}{10}$ of the total annual loss at present sustained it would be more than enough for the purpose.

Finally, an estimate of the number of times the city has been burnt completely during the last 224 years, based upon the foregoing facts, may be of interest. We have the four great fires during the last 13 year, the total length of which is 86 *cho*. During this period, the area of houses destroyed by all fires is 677,067 *tsubo*. The average total area of houses during the last 224 years must have been about double the present area or about 6,000,000 *tsubo*, and the total length of 93 great fires is 3234 *cho*; so that we may have the proportion:—86:677,067 ::3,234:26,623,659. Dividing this total area of the burnt houses during the last 224 years, by 6,000,000 *tsubo*, we get the number required to be 4.4 that is, the city has been burnt every 50 years, which is not very far from the estimate, made in the beginning of this paper.

TABLE A.

No.	Year.	Month.	Day.	Direction.	Magnitude.
1	1657	3	2	NW	48
2	„	„	3	N	53
3	„	„	„	„	40
4	1660	2	24	„	16
5	1661	„	26	„	33
6	1668	3	13	NW	46
7	„	„	13	„	21
8	„	„	16	N	43
9	„	„	18	NW	21
10	1676	12	11	„	17
11	1682	2	5	N	58
12	1683	1	25	NW	58
13	1695	3	22	N	43
14	1697	11	30	„	36
15	1698	10	9	S	83
16	1699	1	10	NW	23
17	„	5	3	S	15
18	1700	2	—	NW	15
19	1702	3	9	N	73
20	1704	1	6	NW	47
21	1706	2	26	„	15
22	1707	„	17	SW	29
23	1711	„	6	NW	25
24	„	„	20	„	15
25	1712	1	18	„	27
26	1716	„	24	N	15
27	„	2	4	„	39
28	1717	3	4	„	56
29	1718	1	29	„	54
30	„	5	30	NW	15
31	1720	„	4	S	53

TABLE A.

No.	Year.	Month.	Day.	Direction.	Magnitude
32	1721	2	4	NW	15
33	„	„	28	SW	38
34	„	3	1	„	45
35	1722	1	26	N	30
36	„	3	5	NW	16
37	„	„	21	SW	30
38	1723	„	22	NW	15
39	„	12	31	N	15
40	1724	4	—	„	51
41	„	5	27	SW	17
42	1725	3	28	„	80
43	1728	1	20	N	41
44	1731	5	20	NW	60
45	1732	4	21	N	32
46	„	„	22	NW	25
47	1737	6	1	S	30
48	1745	3	14	N	68
49	1746	4	19	S	70
50	1756	12	14	N	20
51	„	„	14	„	42
52	1760	3	21	„	43
53	„	2	22	NW	43
54	1771	3	8	N	20
55	„	10	—	S	40
56	1772	4	1	SW	133
57	„	„	1	„	25
58	1778	3	10	NW	25
59	1784	1	12	„	25
60	1785	2	5	N	25
61	1786	„	20	NW	40
62	„	„	21	N	16

TABLE A.

No.	Year.	Month.	Day.	Direction.	Magnitude.
63	1786	3	5	N	16
64	1792	9	7	SW	51
65	1793	11	28	N	28
66	1794	2	9	NW	31
67	1797	12	9	„	30
68	1799	1	11	S	15
69	1804	„	22	SW	81
70	1809	2	14	„	50
71	1811	3	5	NW	45
72	1818	11	15	„	33
73	1824	1	25	N	16
74	1829	4	24	„	35
75	„	5	8	SW	15
76	1834	3	16	N	33
77	„	3	19	„	21
78	1838	5	10	SE	15
79	1842	4	17	S	41
80	1844	2	15	N	15
81	„	5	22	S	18
82	1845	3	2	N	45
83	1846	2	10	NW	50
84	1850	4	16	N	38
85	1855	„	17	SW	15
86	1858	3	24	NW	20
87	1859	1	18	N	21
88	„	3	26	S	55
89	1866	12	15	N	28
90	1872	4	3	NW	23
91	1876	11	29	N	18
92	1879	12	26	NW	15
93	1881	1	26	„	30

TABLE B.

	E	NE	N	NW	W	SW	S	SE	TOTAL
January	0	0	6	6	0	0	0	0	12
February	0	0	7	9	0	3	0	0	19
March	0	0	13	9	0	3	1	0	26
April	0	0	4	2	0	4	3	0	13
May	0	0	0	2	0	2	3	1	8
June	0	0	0	0	0	0	1	0	1
July	0	0	0	0	0	0	0	0	0
August	0	0	0	0	0	0	0	0	0
September	0	0	0	0	0	1	0	0	1
October	0	0	0	0	0	0	2	0	2
November	0	0	3	1	0	0	0	0	4
December	0	0	4	3	0	0	0	0	7
Total	0	0	37	32	0	13	10	1	93

TABLE C.

	E	NE	N	NW	W	SW	S	SE	TOTAL
January	0	0	177	210	0	0	0	0	387
February	0	0	202	249	0	97	0	0	548
March	0	0	554	257	0	155	55	0	1021
April	0	0	156	48	0	254	126	0	584
May	0	0	0	75	0	32	86	15	208
June	0	0	0	0	0	0	30	0	30
July	0	0	0	0	0	0	0	0	0
August	0	0	0	0	0	0	0	0	0
September	0	0	0	0	0	51	0	0	51
October	0	0	0	0	0	0	123	0	123
November	0	0	82	33	0	0	0	0	115
December	0	0	105	62	0	0	0	0	167
Total	0	0	1276	934	0	589	420	15	3234

Note.—In charts C and D, the totals (number of fires from various directions) are put down slightly different from those in the table, by mistake. As it does not change the general character of the curves, the curves are not corrected.

Chart A.

Showing 1st the total number of fires in each month during the last two hundred years

2nd the number of miles of wind in each month (mean of 1879 and 1880).

甲

第一區 各月中大火災ノ全數ノ圖

但シ明暦三年ヨリ明治十四年ニ至ル

第二區 各月中風ノ全量ノ圖

但シ明治十二年十三年ノ平均

Jan.一月 Feb.二月 March.三月 April.四月 May.五月 June.六月 July.七月 Aug.八月 Sept.九月 Oct.十月 Nov.十一月 Dec.十二月

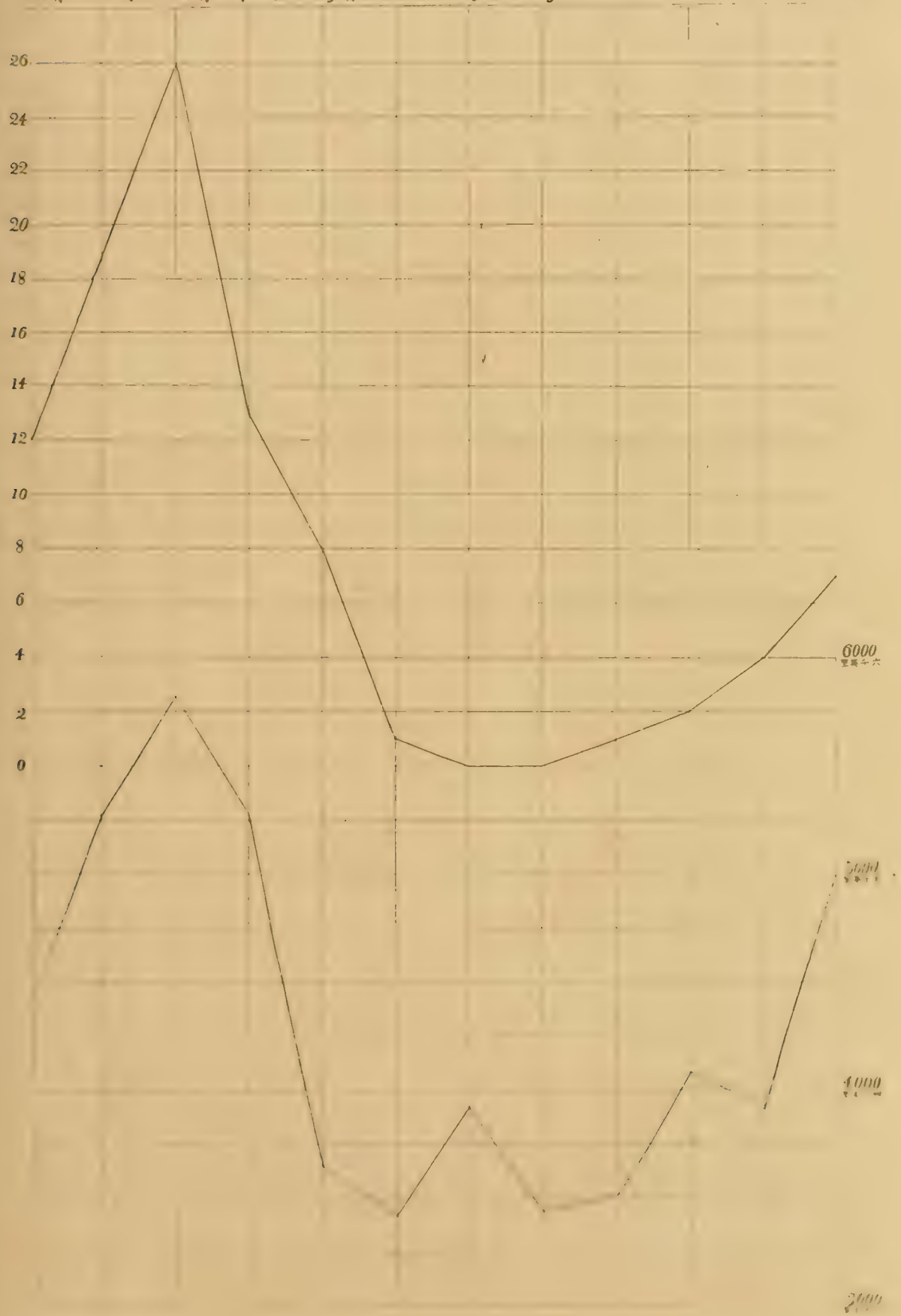


Chart B.

Showing 1st. the total number of fires in each month during the last two hundred years

2nd. the number of high winds in each month (mean of 1879 and 1880).

甲 中 二年十三年 但シ明治十 ノ圖

乙 第一區 各月 中大火災ノ全 數ノ圖 但シ明暦三 年ヨリ明治 十四年ニ至ル 第二區 各月 中烈風ノ全數 ノ圖

Jan.一月 Feb.二月 March三月 April四月 May.五月 June.六月 July.七月 Aug.八月 Sept.九月 Oct.十月 Nov.十一月 Dec.十二月

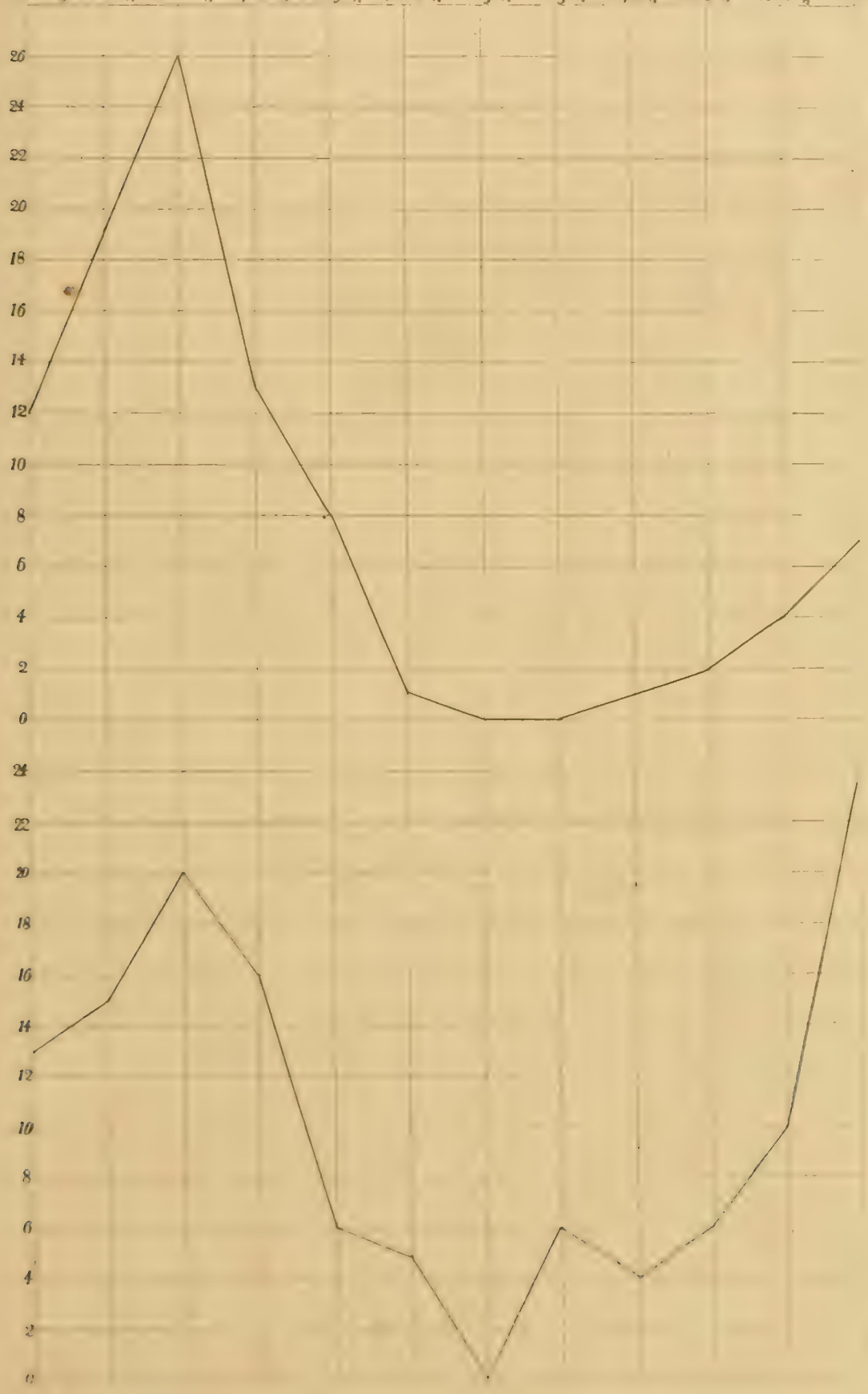


Chart C.

Showing 1st. the total number of fires in different directions during the last two hundred years.

2nd. the number of miles of wind in different directions (mean of 1879 and 1880)

丙 第一區 大火災ノ全數ト方向トノ關

丁 但シ明治十二年十三年ノ平均

戊 但シ明暦三年ヨリ明治十四年三至ル第二區風ノ全量ト方向トノ關

E 東　SE 東南　S 南　SW 西南　W 西　NW 西北　N 北　NE 東北

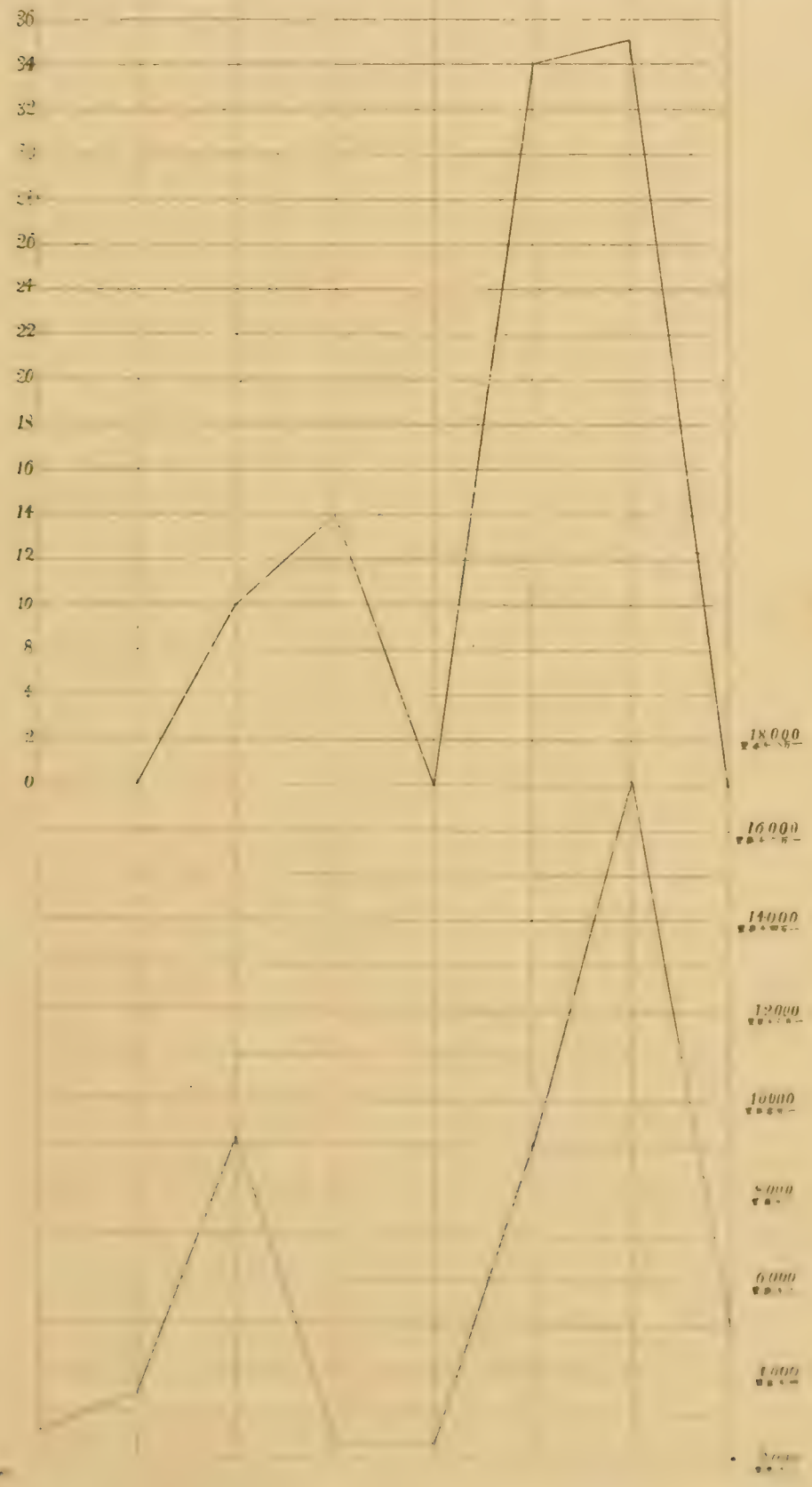


Chart D.

Showing 1st the total number of fires in different directions during the last two hundred years.

2nd the number of high winds in different directions during 1879 and 1880.

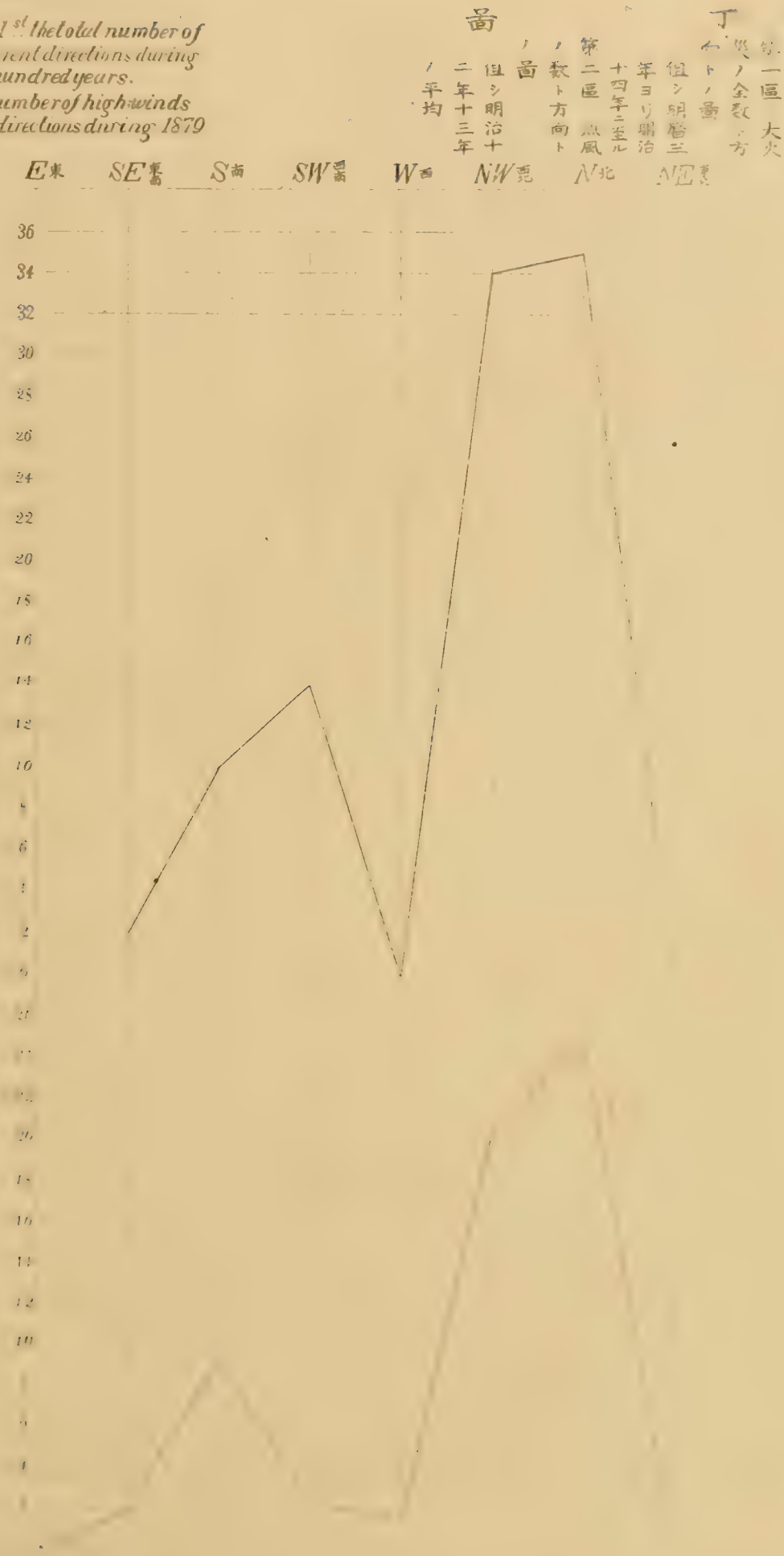


Chart E.

Showing the relative magnitudes of fires which occurred on different days of year.

戊 各大火災長短比較圖

一月 Jan.

二月 Feb.

三月 March

四月 April

五月 May

六月 June

0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150

Chart E.

Showing the relative magnitudes of fires which occurred on different days of year.

各大火ノ長サヲ比較シタル圖

七月
July.

八月
Aug.

九月
Sept.

十月
Oct.

十一月
Nov.

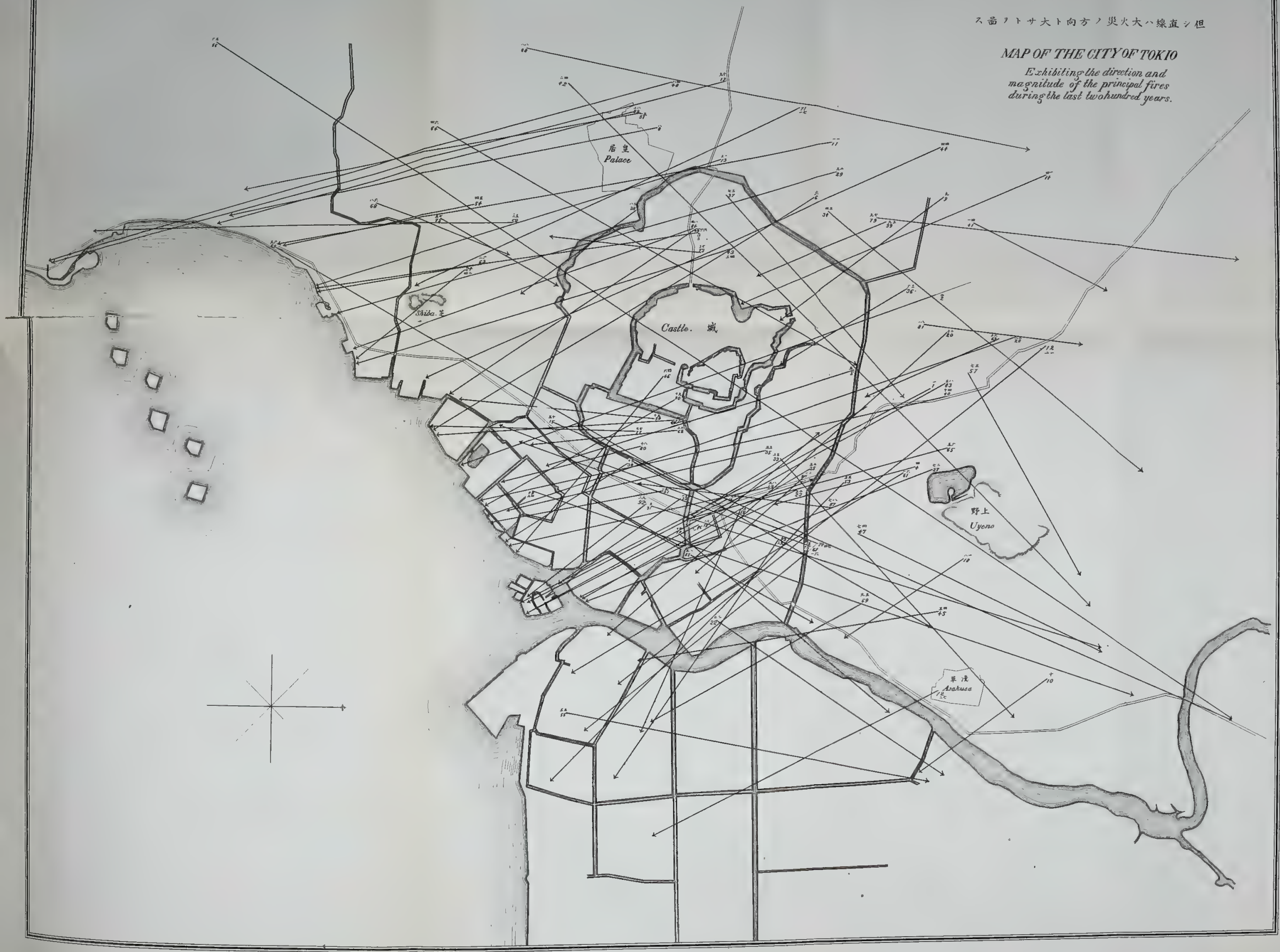
十二月
Dec.

東京圖

但シ直線ハ大火災ノ方向ト大サトヲ示ス

MAP OF THE CITY OF TOKIO

Exhibiting the direction and magnitude of the principal fires during the last two hundred years.



MEMOIRS

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No. 8.

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BY

T. C. MENDENHALL, Ph. D.

Professor of Experimental Physics in Tokio Daigaku.

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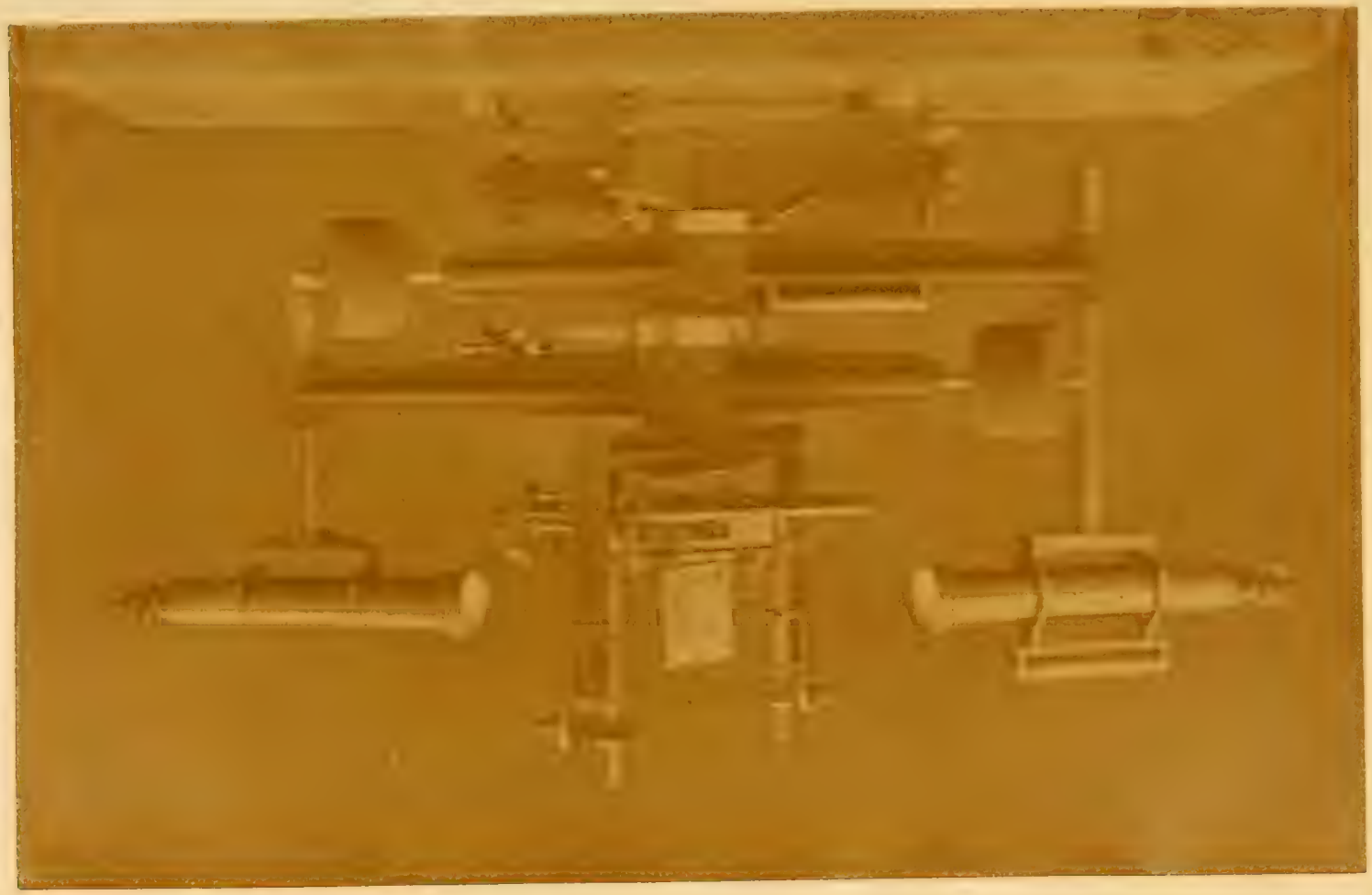
TOKIO:

2541 (1881.)



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THE
WAVE-LENGTHS
OF
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SOLAR SPECTRUM.

The following pages contain the results of a series of wave-length measurements made during the months of November and December 1880. It may be well, in the beginning, to explain why it was considered desirable that these measurements should be made and the results published.

The length of a light wave of given color has for several years ranked among the most accurately determined physical constants. In 1868 Angström published his "Recherches sur le Spectre Solaire" which contains the results of his elaborate determinations of the wave-lengths of many hundreds of the dark lines. This work, involving as it did great labor both in observation and reduction, must always stand among the most perfect of its kind and it is justly referred to by a well known writer as "characterized by such accuracy and completeness as to render it worthy of the highest admiration, to be regarded as a pattern to all investigators." Indeed if these results could be considered strictly reliable further work in this direction would be almost unnecessary, as there are only a few spectroscopic researches in which a greater degree of accuracy would be demanded.

In addition to the work of Angström numerous contributions of wave-length measurements have been made from time to time by other physicists. As regards measurements of the dark lines of the solar spectrum, the principal of these, as far as I am aware, are by Ditscheiner, van der Willigen and Mascart. Many of these measurements have been made since the publication of Angström's work and, apparently, under equally favorable circumstances. But every student of spectroscopy is aware of the fact that these measurements differ very considerably among themselves. One only need examine such a table as is given in the introduction to "Watts's Index of Spectra," in which various measurements of the same line are placed side by side, to be convinced that the lack of agreement is so great, in many instances, as to throw all of the results seriously in doubt. Angström, in his memoir, compares the results obtained by Ditscheiner, van der Willigen and Mascart with his own, but Ditscheiner published a revised series at a later period which differ still more from those of Angström.

In order that the extent of these differences may be seen I give below a table of differences in the wave-lengths of the principal lines, the numbers being obtained by subtracting Angström's wave-length from that of each of the others, the unit here and throughout this paper being the generally accepted tenth-metre. Angström's numbers are his final "definitive values" given in his memoir. I am not able to refer directly to the original memoirs of either of the others and in thus quoting at second-hand some errors may be committed. Ditscheiner's numbers are taken from a table given in the *American Journal of Science* for April 1872 which was copied from his paper by Professor Gibbs and gives the recomputed values. The values credited to van der Willigen are from the same source and those of Mascart are from Angström's memoir. The numbers under D belong to Ditscheiner and those under V. W. and M. to van der Willigen and Mascart.

	D.	V.W.	M.
B	7.	4.22	— 0.5
C	0.2	3.47	— 1.4
D_1	2.27	3.31	— 0.83
D_2	1.98	3.18	— 1.12
E	1.81	2.44	— 1.69
b_1			— 1.1
b_2	1.84	3.06	
F	1.46	3.26	— 0.94
G	3.95	4.12	+ 0.30

Of these results, those of Mascart agree most nearly with Angström's tables, but even here the difference amounts to a maximum of nearly two units in the case of E. It will be seen that not only do these authorities differ from Angström but they also differ from each other. In the measurement of wave-length the most difficult thing to determine is the value of the grating space. An error in its value will not, however, influence the *ratio* of the wave-lengths. From the nature of the differences exhibited in the above table it is clear that they cannot be accounted for on the supposition of error in the grating space alone, but that among them all, including, of course, those of Angström, there must somewhere exist serious errors in angular measurement and doubtless errors in space determinations beside. When these differences amount, as they do among these observers, to several units, they are sufficient to influence materially much spectroscopic work in which reference is made to absolute wave-length, according as one or the other is accepted as correct.

The University having received from the makers, early in the year 1880, a spectrometer of unusual power and excellence of construction and also a number of diffraction gratings ruled by Mr. Chapman upon L. M. Rutherfurd's machine, of which one or two are unusually good, it appeared to me to be desirable to make immediate use of it in the measurement of the wave-lengths of several of the principal lines. It was not thought necessary to extend the work beyond a

few of the principal lines; at least not until a comparison of the results with those of Angström and others should indicate that it was desirable. Angström based nearly all of his work upon micrometric measurements from these principal lines and if it can be shown that they are at least *relatively* correct there is strong presumptive evidence in favor of his micrometric measures. Concerning my instrumental appliances, a comparison with those used by Angström (I have been unable to find descriptions of the spectrometers used by the other observers referred to) will show that in some respects, at least, they are decidedly superior. In dimensions and fineness the grating far exceeds his, giving much greater dispersion and, doubtless, superior definition and the angular measurements were capable of being made with a greater degree of precision. In short, even if *the value of the grating space was unknown*, I ought, with reasonably good observation work, to be able to decide in favor of one or the other of these discordant sets of results, or, possibly, against them all.

The work was done during the months of November and December on account of the unusually clear weather which nearly always prevails here at that season; the prevailing low temperature at that time of the year is, however, an objection.

THE SPECTROMETER.

The general construction and relative dimensions of the various parts of the instrument are shown in the accompanying photograph. The instrument was made in the winter of 1879-80 by Messrs. Fauth and Co. of Washington D. C., U. S. A. The mechanical execution of the work was excellent in every respect and highly creditable to the makers, whose reputation for the production of instruments of precision is well established.

For many valuable suggestions concerning the details of its construction and for a careful examination of the instrument after its completion and before it was sent to Japan, I am indebted to Professor C. A. Young of Princeton College, and I wish to acknowledge with gratitude this, among the many obligations under which he has placed me and, indeed, every student of spectroscopy.

The dimensions of the instrument are nearly as follows;—

Diameter of Circle	30 cm.
Length of View & Collimating Telescopes	35 cm.
Aperture „ „ „ „	5 cm.
Height,—to circle	32 cm.

The circle is divided to spaces of 5′ each. It is read by two microscopes diametrically opposed to each other, the eye pieces of which are provided with micrometers, one turn of the screw being equal to 1′. The micrometer screw heads are divided into sixty parts, thus carrying the reading to single seconds. The various parts are capable of almost every desirable movement relative to each other. The lower arm, supporting the collimating telescope, swings completely

around the vertical axis carrying all that is above along with it. The second arm, supporting the view telescope, swings around independent of the collimator and circle but carrying with it the reading microscopes which are attached to it by a strong cross beam at right angles. The circle has a movement independent of everything below it and the table upon which the grating is placed also rotates independent of the circle. The position of this table may be read, when necessary, by means of two verniers placed opposite to each other. All of the movements are, of course, provided with the necessary clamp and tangent screws. It will be observed that the arms supporting the view and collimating telescopes are provided with balancing weights so that both ease of motion and stability are secured. The eye piece of the view telescope is provided with a micrometer, as is also the collimator for measuring and adjusting the width of the slit. A striding level is provided for the telescope and collimator and levels are also attached to the arm of the collimator and to the grating table. The latter has screws for leveling and for centering.

The instrument was mounted upon a stone pier in a small building erected for the purpose, the inside walls of which were blackened. The direction of the collimator was nearly North and South. Through a small opening in a shutter opposite the collimator a beam of light was thrown from a heliostat mounted upon a pier just outside.

ADJUSTMENTS.

It will be seen that all necessary adjustments can be made with little difficulty. The axis of the instrument is made vertical by means of the levels. The telescope and collimator are adjusted for height and direction by means of the vertical pillars upon which they rest, which have movements in a vertical direction and about vertical axes. The telescope and collimator and the grating table are then leveled. The adjustment of telescope and collimator for parallel rays is easily accomplished by means of the collimating eye-piece, using the surface of the grating as a reflector. The advantage in using this form of eye-piece in this work is very great. Each telescope is adjusted to its focus independent of the other and when it is desirable to render either telescope or collimator normal to the grating it is accomplished accurately, quickly, and without the aid of the circle. The slit and cross wires are adjusted to the line of collimation by turning the telescopes in their supporting Y's. The face of the grating is rendered vertical by means of adjusting screws arranged for the purpose, using the reflected image of the cross wires. To make the lines of the grating vertical, a diaphragm is placed over the slit so as to reduce greatly its length. A very narrow spectrum results and it is easy to adjust the grating so that this appears in the same position on both sides of the collimator.

The method adopted for making the observations, being that of normal incidence, is discussed in detail in another place. A setting was made upon the

line on one side, both microscopes were read and the telescope was moved to the other side and set upon the same line and the reading taken again. The temperature of the grating was noted after each setting. This was always repeated several times and then the circle was unclamped and turned through an angle of from 20° to 60°, the grating was again made normal to the collimator and the angular measurements resumed. The ease with which the grating could be adjusted by means of the collimating eye-piece reduced the labor of working over different portions of the circle very greatly and, besides, it was easy at any time to examine this adjustment so as to be sure that the grating had not been disturbed from its position. At frequent intervals during the measurements the instrument was readjusted throughout, in order that no constant errors due to false adjustments might influence the results.

THE GRATING.

The University possesses four diffraction gratings ruled by Mr. Chapman. Three of these are upon metal and one is on glass. I am informed by Mr. Chapman that the composition of the metal is of copper and tin in the ratio of 17 parts of the former to 8 of the latter.

The metal gratings are square, each side being 7.5 cm. in length. The thickness is 7.7 mm. The ruled surface covers about 20 square centimeters. The finest of the three consists of about 30000 lines, nominally ruled at the rate of 17296 to one English inch. This grating has great dispersive power, therefore, separating the D lines in the spectrum of the second order a trifle less than 5′, and in addition to this the definition is most excellent. In consequence of these facts this grating was selected as being the most desirable for the work of precise measurement of wave-lengths and, with the single exception noted in the results given, the measurements were made upon the spectra of the second order. There are one or two peculiarities about the spectra produced by this grating, found also to exist in a less degree with the others, which are worthy of a moment's notice. The most notable of these is the inequality in brightness of spectra of the same order on opposite sides of the normally incident rays. This is noticeable in spectra of both the first and second orders but is much more marked in the latter.

The intensity of illumination at any point in a plane at right angles to the lines of a diffraction grating is generally expressed in the shape of a function consisting of the product of three terms. When a certain relation exists between the second and third terms, spectra of a certain order will disappear entirely and when this relation exists approximately, these spectra will be correspondingly faint.

The order of the spectra thus affected is determined by the relation between the whole grating space and the reflecting surface which remains after the groove is cut out, or between the opaque and transparent spaces in a ruling upon glass.

It is, therefore, not uncommon to find spectra of certain orders much fainter than others. But as far as this cause is concerned, it affects alike spectra on both sides of the incident beam and the explanation of the inequality referred to must be looked for elsewhere.

It seems natural, of course, to look for the cause in some lack of symmetry of the thin reflecting surfaces, in reference to the normal line, produced in the operation of cutting the lines in the metal.

To establish the existance of this an examination of the grating was made by means of polarized light. It is well known that if light, polarized in the plane of incidence, be reflected from a metalic surface the reflected beam will remain polarized in the same plane. If the plane of first polarization is not identical with that of incidence the reflected ray is elliptically polarized and if examined in the ordinary way it will, in general, present the appearance of being polarized in a plane inclined to that of first polarization. The grating was arranged so as to reflect a beam of light polarized in the plane of incidence and in such a way that it could be shifted about in its own plane and also turned about a normal axis. It was at once observed that when the light was reflected from the ruled surface of the plate, the ruled lines being nearly parallel to the plane of incidence, a decided change in the plane of polarization took place. When the grating was turned through an angle of 180° about a normal axis the inclination of the plane was on the opposite side. When the lines were at right angles to the plane of incidence no change of polarization could be observed.

From this it seems probable that in the process of cutting the grooves in the metal each narrow reflecting surface had been slightly tipped out of the general plane, towards that part of the surface already ruled and this would evidently have the affect of increasing the brightness of the spectra on that side at the expense of those on the other. Another grating was then examined in the same manner, the relative brightness of the spectra on different sides not being known. The change in the plane of polarization was not so marked in this as in the other, but it was very readily distinguished. In this the grating space is twice as wide as in the first and it is evident that the disturbance of the plane of reflection is not likely to be so great. It was easy to predict, however, on which side of the normal the spectra would be faint and, in the hands of an observer who was entirely ignorant of the examination that had been made, this prediction was at once verified. The microscopic examination of these metallic gratings is difficult owing to the difficulty of illumination when an objective of sufficiently high power is used. A good illumination was finally secured, however, by throwing the light in a plane nearly parallel to the surface of the grating. When this was done the appearance presented was exactly in accordance with what had been anticipated. When the light was received from the side towards which the narrow reflecting surfaces were tipped, as indicated by the polarization experiments, these surfaces were easily and distinctly visible as bright lines; when the grating was turned in its own plane through 180° from this position it was only with the

greatest difficulty that the lines could be distinguished at all. Finally another observer was requested to determine the effect, if any, upon the relative brightness of the spectra on different sides of the collimator, produced by varying the inclination of the grating to the collimator and the results agreed precisely with the foregoing hypothesis.

There is another defect in this grating which seems to me to be likely to exist in all gratings of a similar space and magnitude. It is the faintness of the illumination at the two extreme ends of the spectrum, especially at the violet end. In the American Journal of Science for November 1880., Professor Young, in describing the excellent qualities of a similar grating, makes the same complaint in regard to the violet end of the spectrum. I am inclined to the opinion that the cause of this is to be looked for in the minor periodic variations in the third factor of the expression for intensity of illumination, referred to above. Besides the great maxima of this function which determine the location of the spectra of the various orders, there are numerous others of extremely small magnitude compared with the first. They are distributed throughout the whole range within which the great maxima are visible and, as they contain the spectral components of white light, they will tend, notwithstanding their extreme faintness, to produce a general illumination of the whole field, so as to destroy, to some extent, the blackness of the background against which the ordinary spectra are seen. Fraunhofer called these "spectra of the second class" and Angström refers to them in his memoir in a discussion of the relative merits of gratings in which a given number of lines is made to cover a great or a small space.—The grating space being constant the number of these minor spectra in a given space will be proportional to the number of lines. But as the brightness of the great spectrum at any point varies as the square of the number of lines it would seem that the one could never overtake the other. When we consider, however, that the minor spectra contain all of the components of white light it seems probable that where, as in the extreme ends of the ordinary or great spectra, the light is, at best, exceedingly faint, that of the minor spectra may be sufficient to nearly overpower it and to render observations difficult in these regions. If this be correct it must be admitted that, while in general there is great advantage in the use of gratings of great fineness, for the examination of the extreme regions of the spectrum a smaller number of lines covering the same space would yield better results. In the present instance it will be observed that neither the A nor the H lines were included in the measurements as they could not be observed with sufficient satisfaction to make a measurement desirable.

METHODS OF OBSERVATION.

In making the measurements necessary to the calculation of the wave-length of any line, the essential parts of the apparatus, aside from the graduated circle, are the slit with collimating lens, the grating and the telescope. In general there will be three different arrangements possible.

The grating may be fixed so that its plane is normal to the collimator; or it may be normal to the telescope; or it may be normal to neither. These arrangements give rise to several different methods of making and reducing observations, each of which seems to possess some advantages peculiar to itself. But it becomes necessary to choose from among these that which, under the circumstances, proves to be the most desirable and, in order to present more clearly the reasons which led to the selection made in the present instance, it may be desirable to present a brief discussion of the principal methods which may be adopted. For this purpose,—let

θ = Angle between the telescope and the normal to the grating.
ϕ = Angle between the collimator and the normal to the grating.
s = The grating space.

Then, in general, we have.

$$\lambda = s\ (\sin\theta \pm \sin\phi)$$

the spectrum being of the first order.

1st. Suppose $\phi = 0$ that is, the collimator is normal to the grating. The formula reduces to

$$\lambda = s \sin\theta$$

and the operation consists in measuring the angle θ which is best done by setting on the line, first one side of the normal and then on the other, and taking half of the angle passed over.

2nd. Suppose $\theta = 0$—or the grating is kept constantly at right angles to the telescope. The resulting formula and process of measurement will be similar to the preceding.

3rd. The telescope and collimator may be kept at a constant angle with each other and the grating moved. The observations and reductions are easily made in the following manner.

Let a = angle between telescope and collimator.
b = twice the angle through which the grating must be turned in order to bring the line and the image of the slit upon the cross wires of the telescope.

θ and ϕ = as before.—

$$\text{then } \theta = \frac{b+a}{2}$$

$$\phi = \frac{b-a}{2}$$

and the general formula reduces to

$$\lambda = 2\, s \sin\frac{b}{2} \cos\frac{a}{2}$$

4th. A method of observation and reduction was used by Angström in which the grating was made nearly normal to the collimator, the deviation from strict perpendicularity being so great, however, that it could not be neglected in the calculations. This method was not used by the writer, because it is especially suitable for transparent rather than reflecting gratings, and also because it was perfectly easy to make the grating so nearly normal to the collimator that it might always be assumed to be accurately so. On account of its being the method used by Angström and in order that it may be compared with that adopted in these observations, it is here included with the others.

Suppose the grating to be of glass and to be adjusted so as to be as nearly as possible normal to the collimator. Readings are then taken with the telescope in three positions; when set on the line on one side; on the image of the slit; and on the line on the other side.

Let a, S and a_1, be these readings

$$\text{let } \frac{a-a_1}{2} = \gamma \text{ and } \frac{a+a_1}{2} - \mathrm{S} = \delta$$

then the formulæ for reduction used by Augström are;—

$$\lambda = s \sin \gamma \cos (\delta + \phi)$$

$$\text{and } \tan \phi = \frac{\cos \gamma}{1-\cos \gamma} . \delta \text{ approximately.}$$

These formulæ are easily developed. As before

let ϕ = angle between collimator and normal
θ = „ „ telescope „ „ in one position.
β = „ „ „ „ „ in the other position.

then we have

$$\text{and} \quad \lambda = s(\sin \theta - \sin \phi) \quad (1)$$
$$\lambda = s(\sin \theta + \sin \phi) \quad (2)$$

$$\text{but} \quad \gamma = \frac{a-a_1}{2} = \frac{\theta+\beta}{2}$$

$$\text{and} \quad \delta + \phi = \frac{\theta-\beta}{2}$$

Adding (1) and (2) and substituting these values, we have;—

$$\lambda = s \sin \gamma \cos (\delta + \phi)$$

Also subtracting (2) from (1) and reducing in the same way,—

$$\sin \phi = \cos \gamma \sin (\delta + \phi)$$

The angle δ will always be small; in Angströms 35 observations upon the E line, the only ones given in full in his memoir, its value was generally less than 3′, reaching nearly 11′ in one case however. Assuming $\delta = \sin \delta$ and $\cos \delta = 1$ and expanding the above, we have

$$\tan \phi = \frac{\cos \gamma}{1 - \cos \gamma} \cdot \delta$$

from which ϕ is computed.

The relative merits of these methods in any particular case will depend largely, of course, on the construction of the instrument and the nature of the grating with which the work is done. Thus, in the present instance, the instrument does not adapt itself readily to the use of the second method and I do not know that it possesses any particular advantages over the first. The grating used prevents the adoption of the fourth method, besides it is unnecessary to resort to the approximation which forms a part of the process of reduction in the use of that method. The choice, therefore, seems to lie between the first and third. From a theoretical stand point the third method is by far the most tempting of all and it certainly offers many advantages. Among these may be mentioned the fact that the mass of matter to be moved in the process of making a measurement is reduced to a minimum, being only the circle and the grating upon it. This motion is also generally much smoother than that of the telescope or collimator and hence, more completely under the control of the observer. Thus the settings will be easier and possibly more precise. Another great advantage is that as the grating has a movement independent of the circle the method of repetition may be introduced. The angle α is measured very easily by first making the grating normal to the telescope, by the aid of the collimating eye-piece, and then turning the grating until the image of the slit is bisected by the cross-wires.

In spite of the numerous attractions offered by this method it was very reluctantly rejected, after several hundreds of observations had been made for purposes of comparison between it and the first, and the latter was accepted as, on the whole, more accurate. There are several objections to the third method, not at first apparent, but which became evident during its use. One of these was that it was found to be impossible to rely upon the constancy of the angle between the telescope and collimator. Sometimes a change would appear to occur suddenly and the magnitude of the change was often so great as to produce a decidedly sensible effect on the resulting wave-length. I attribute these changes to the effects of change in temperature upon various parts of the instrument; a sudden shifting taking place when the stress due to expansion reaches a certain amount. Of course the real movement is exceedingly minute but it is sufficient to produce a perceptible effect on the angular measurements. The existence of these changes renders frequent measurements of the angle between the telescope and collimator necessary. As the collimating eye-piece is a necessity in these

measurements a change must be made if higher powers are in use in the line observations.

Again, it was found that it was unadvisable to make numerous repetitions of an angle, except when the temperature was unusually constant, for to make the temperature correction it was desirable to know the temperature corresponding to each setting rather than to depend upon temperature observations made at the beginning and end of a series. Finally the measured angle, that through which the grating was turned, was much smaller than the corresponding angle in the first method and in consequence the results, which depend upon the sines of these angles, are affected to a greater extent by small errors. A glance at the formula shows that it is desirable to make a as small and b as large as possible. With a reflecting grating a cannot be diminished beyond a certain limit; that is, with a spectrometer of ordinary construction. An instrument of what may justly be called "extraordinary" construction has recently been made by Alvan Clark & Sons for Princeton College U. S. A. In this instrument the collimator and telescope are one, as far as the use of the same tube and object glass goes. It is obvious that this ingenious plan gives the maximum efficiency in certain operations, and if some optical difficulties which present themselves can be entirely overcome this instrument will doubtless take rank as the most accurate existing means of investigation in this direction.

Concerning the first method, which was finally adopted, there are one or two difficulties, which appear to be of considerable moment at first, but which are found to be manageable in practice. With a reflecting grating it is, in general, necessary to swing the telescope through at least two thirds of the whole circumference in making a single pair of readings. While in this case the mass to be moved is much greater than in the previous method, yet the excellence of the construction of the instrument is such that very little is lost in the way of smoothness of motion and delicacy of setting and much is gained in the firmness and stability of the instrument by the considerable weight of its various parts. Repeated examinations have shown that the various movements are entirely independent of each other and the motion of the telescope never produces any sensible disturbance of the other parts. By the use of this method, advantage cannot be taken of the principle of repetition as it can in that of oblique incidence. But it is believed that most of the advantages of repetion have been secured and at the same time the objection to it has been avoided. The ease and rapidity with which the grating could be made normal to the collimator was such that measurements could be readily made over different parts of the circle in succession and thus the errors of graduation eliminated as far as possible. The temperature correction, which is very important, was secured by reading the thermometer immediately after each setting upon a line. Finally, it may be urged that we can never be certain that the grating is absolutely normal to the collimator. This is quite true, but it is also true that the error in this adjustment may be considerable without sensibly affecting the result.

To investigate this question suppose that a reflecting grating is used and that we look in the direction of the collimator, towards the grating;

let θ = angle between telescope and normal on the right
θ_1 = " " " " " " " left.
a = " " collimator " "
b = " " " " telescope on the right
b_1 = " " " " " " " left.
b_n = " " " " " for strictly normal incidence.

$$\text{then } b = \theta - a \text{ and } b_1 = \theta + a$$

and we have for the spectrum of the first order—

$$\frac{\lambda}{s} = \sin(b + a) + \sin a \quad \text{(R)}$$

$$\frac{\lambda}{s} = \sin(b_1 - a) - \sin a \quad \text{(L)}$$

the normal to the grating being supposed to be thrown slightly to the left.

Differentiating and supposing $a = 0$ we have

$$db = -(1 + \sec b)\, da$$

$$db_1 = (1 + \sec b_1)\, da$$

and the error in taking $\frac{b + b_1}{2}$ for b_n will be

$$(\sec b_1 - \sec b)\, da$$

An examination will show that if b_n be 45° and the grating be as much as 5′ away from its true position this error will be less than half a second. To facilitate and increase the accuracy of this adjustment the brass jaws of the slit were blackened and then when the collimating eye-piece was placed in front of the slit and properly illuminated a very clear and well defined image was produced by reflection from the grating. It was found that the adjustment could be made very quickly and within one or two seconds. It is safe, therefore, to assert that the results are entirely free from any sensible error originating in this adjustment.

CORRECTION FOR TEMPERATURE.

To make the reductions for temperature it is necessary to know the temperature at which settings were made and the co-efficient of expansion of the material of which the grating is composed. It is believed that the first has been accomplished with a degree of accuracy exceeding that in the case of any series of measurements hitherto made. Angström admits and deplores the difficulty

or impossibility of knowing exactly the temperature of his grating. In the use of a transparent grating it is not easy to see how its temperature could be measured, but there exists the compensation that the co-efficient of expansion of glass is so much less than that of a metallic reflector that it becomes less important. In these measurements a small rectangular vessel of thin copper was sealed to the grating which itself formed one side of the cup thus formed. This was filled with water in which a small thermometer was constantly immersed. As the changes in temperature were never very rapid the reading of this thermometer can differ but little from the true temperature of the grating. The thermometer was compared with a standard and table of corrections prepared.

As far as I could learn in the beginning, no determination had been made of the co-efficient of expansion of the alloy from which these gratings are made. A series of observations was therefore undertaken, for the purpose of ascertaining this from the grating itself by means of angular measurements made upon the same line at different temperatures. If we take the equation—

$$\lambda = s \sin b$$

in which λ represents wave length, s the grating space and b the angle of deviation, we obtain by differentiating—

$$\frac{ds}{s} = -\cot b \, d\, b$$

When the increment of temperature is 1° the left hand member represents the co-efficient of expansion. It will thus be seen that this can be determined without any knowledge of the wave length of the line set upon or of the value of the grating space. In the first series of experiments an attempt was made to carry the grating alone through a range of 5° or 10° of temperature, that of the surrounding air remaining sensibly constant. The grating was made to take the place of one side of a wooden box which was filled with water whose temperature was changed as desired. It was found to be difficult to prevent a slight shifting in the position of the grating, due to the changes in temperature of the box and its support on the table of the spectrometer, and the temperature could not be maintained constant for a sufficient length of time to enable observations to be made on both sides of the collimator so that the effect of this slight change in position might be eliminated. And besides, the difference of temperature between the two faces of the grating caused it to warp slightly which injured the definition if it did not otherwise interfere with the accuracy of the results. In a brief article in the *American Journal of Science* for March 1881, I described this mode, of making the determination and gave the results of a series of measurements. The objections to the methods were at that time fully appreciated and a more reliable process was indicated. The opinion was also stated that the result there given was more likely to be too high than too low. In fact when I came to apply this correction to the regular

observations, especially in the case of one or two lines in the measurement of which great care had been taken, it proved to be a correction which would not correct. It therefore became necessary to make a redetermination of this constant. It was found upon trial to be possible to raise the temperature of the room in which the spectrometer was mounted, as high as 18° or 20° C., when the temperature outside was much lower and to keep it nearly constant for a considerable length of time. A series of measurements was therefore made upon a fine line, near to b_1, while the temperature of the room was low and then afterwards it was raised to about 18° and another series made upon the same line. This plan avoided the principal difficulties met with in the preceding and the result is, without doubt, much more reliable. The lower temperature was nearly 4°, the results being reduced to that, and the upper differed little from 18°, to which the measurements at the high temperature were reduced. Thus there was a range of 14° which is greater than that of the previous determination.

From these observations the following was obtained;—

$$db = 3''.89 \pm 0.''03$$

$$b = 44°\ 56'\ 50''$$

and for the coefficient of expansion

$$e = .0000189$$

the probable error of which is less than one percent of the whole. The result of the first determination was,— $e = .0000202$ and without doubt there existed some source of constant error which was not detected.

The direct method of applying this correction would be, of course, to determine the value of the grating space for such degree of temperature at which an angular measurement was made. It has been found to be much more convenient, however, to apply it directly to the angular measurement itself. If b and b_1 be the angles for the two lines we shall have, since e is constant,—

$$\cot b\, db = \cot b_1\, db_1$$

$$\text{or} \qquad db_1 = \frac{\cot b}{\cot b_1}\, db$$

Thus having determined the value for one line, by observations at different temperatures, that for any other line can be easily computed.

In this way all of the angular measurements have been reduced to a common temperature of 18°, which is also the temperature assumed for the grating space.

CORRECTION FOR BAROMETRIC VARIATION.

The observations may be assumed to have been made, in general, under a standard pressure of 760 mm. With a single exception, it has happened that

the measurements were made upon days during which the fluctuation of the barometer from the normal was very small, generally not more than one or two millimetres at the time of making the reading. The exception was on November 26, when the height was about 10 mm. below the normal at the time of making some measurements upon the E line. These measurements have been corrected for this difference but this correction has not been introduced in any other other instance as it has not amounted to more than a small fraction of a second, and its effect will doubtless be eliminated from the general mean, owing to the fact that these small fluctuations were about as often on one side of the normal height as on the other.

THE VALUE OF THE GRATING SPACE

By far the most difficult quantity to determine with accuracy is the value of the grating space. When angular measurements can be made with the precision which it is believed has been reached in these determinations, the comparison of the space of one grating with that of another can be made with a degree of accuracy probably exceeding that attainable by ordinary methods. For this purpose the gratings need not be brought together, the length of a wave of light being a common measure easily applied to both. The value of the space of one grating may be made to depend, therefore, upon that of another, the absolute length of which has been ascertained with great care, provided both have been employed in precise angular measurements upon one and the same line.

Instead of this a direct comparison of the grating space with a standard unit of measure may be undertaken. Where the first method is possible it is vastly more convenient and, in general, more accurate than the last. Although at least two Metres of well determined length are available in Japan, no comparing apparatus suitable for such work could be obtained and it was, therefore, not only desirable but necessary to rely, if possible, upon the first method for the determination of the grating space. During the progress of the observations I had hoped and expected to be able to make such a comparison between this grating and another whose space had been determined to a great degree of precision. Mr. C. S. Peirce of the U. S. Coast Survey, has been engaged in a series of observations of great interest and value for the comparison of a wave-length of light with a standard metre. The operation includes, of course, the accurate measurement of the angle of deviation of a certain line, produced by a grating whose space is definitely known.

Unfortunately I have not been able to procure the results of this investigation, indeed I believe the final comparison of the grating with the metre has not been entirely completed. I am therefore unable to give the value of the grating space with that degree of certainty which was at first expected and

which would be so desirable. It must be remembered, then, that the results do not possess that value as *absolute* wave-lengths which I believe would otherwise belong to them. Their *relative* value is not altered, however, by this fact and I hope to have furnished the data by means of which, at any future time when it becomes possible, such slight corrections as may be necessary may be easily applied. It is believed that the value of the grating space assumed is *very close* to the true value and that the corrections to be applied hereafter will be very small.

The following are the facts in regard to the grating space as far as at present known.

The grating is marked by the maker "17296 lines to one inch." I am also informed by Mr. Chapman that it is attempted to keep the temperature as nearly constant as possible at 65° F. during the process of ruling, but that as the ruling of a large grating occupies several days the temperature often fluctuates two or three degrees above and below that point. The temperature to which these observations have all been reduced is 18°, which is very nearly that at which the ruling was made. This number, 17296 to one inch, is equivalent to 680.957 to one millimetre and were the inch of the machine known to be correct this number might be accepted. But Mr. Chapman says that one English inch is undoubtedly less than 17296 of these divisions by one or two divisions.

In his "Measurements of Gravity at Initial Stations in America and Europe"* Mr. Peirce has given the result of an elaborate examination of a centimetre ruled upon Mr. Rutherfurd's machine. The concluding sentence of this discussion is as follows;—

"This centimetre is equal to $6809\frac{1}{2}$ teeth of Rutherford's machine, and as it is $\frac{1}{1000}$ too long, we conclude that 6809 teeth make a centimetre at ordinary temperatures, say about 18°." As this temperature agrees with that at which the grating was ruled and also that to which the observations have been reduced, it is the most accurate determination at present available and in all of the following reductions the spaces have been assumed to be 680.9 to one millimetre. This number is not free from doubt, however, as is evident from the fact that the temperature at which this particular grating was ruled may not be exactly identical with that of the above comparison and besides there is room for doubt as to the accuracy of the decimetre of comparison and Mr. Peirce justly remarks that "all exact measures of length made now must wait for their final correction until the establishment of the new metric prototype". It is likely therefore that the assumption made is the best possible under the circumstances.

In order that it might be possible to correct these results, if necessary, by means of the method of comparison of angular measures, I have endeavored to connect the series with Mr. Peirce's angular measures for the comparison of a wave-length with a metre. For this purpose I have referred to the only published

* Appendix No 15—Report of 1876—U. S. Coast Survey.—Printed at Washington—1879.

account of his results that I know of, which is to be found in the *American Journal of Science* for July 1879. Unfortunately, the data given there are not sufficient to enable me to determine with absolute certainty the line set upon. Mr. Peirce made two series of observations; in the first he measured the deviation of a spectral line, "van der Willigen's No 16," "using a certain gitter of 340½ lines to the millimeter". I have not been able to refer directly to van der Willigen's measurements to ascertain the position of his "No 16" but as Mr. Peirce's grating space was double mine I have endeavored to locate it from his measures. I have assumed that the work was done in the spectrum of the fourth order. Although nothing is said of the order of the spectrum in the article referred to, it is clear that no other supposition would be admissible. This line should, therefore, have the same deviation in the spectrum of the second order of the grating used in these measurements. Mr. Peirce says nothing about the temperature at which his measurements were made so that there is room for some variation on this account.

Upon examining the spectrum at this particular deviation there appeared to be no line at that point which seemed to me to possess sufficient distinctness and prominence to have been selected for this important duty. A well defined and sufficiently prominent line very close to the indicated point, a little nearer b_1, seemed to be most probably the line upon which the settings had been made. This line was accordingly selected and a considerable series of careful measurements were made upon it. Assuming this to be the same line used by Mr. Peirce, the difference is not greater than can easily be accounted for. His result is

$$b = 44^\circ\ 57'\ 9''.75$$

and my own, the mean of 34 measures which will be found in detail in the following pages, was;—

$$b = 44^\circ\ 56'\ 50''.35$$

the difference being 19″.4

Mr. Peirce does not state the temperature to which his results were reduced. With my own grating the increment of arc for this line was 3″.89 for 1°C, so that it is clear that there is a possible variation in temperature easily sufficient to account for the difference in the angular measurements, especially when it is remembered that the gratings may have been ruled at different temperatures and that they are composed of substances widely differing in their co-efficients of expansion.

The second series of measurements made by Mr. Peirce was upon another line near the first and with "another much finer gitter." As this is a region crowded with lines and as the fineness of the grating, was not definitely stated, it was impossible for me to decide certainly as to the line made use of, so it was determined to rely upon the first results, which are undoubtedly of sufficient accuracy, assuming that the right line has been found.

If the exact value of Mr. Peirce's grating space was known, that of the grating used in these measurements could be at once ascertained with a degree of accuracy equal to that of the angular measurement of this line and whenever the final comparisons are completed it will be easy to apply the necessary corrections.

MICROMETRIC MEASUREMENTS.

Micrometric measures were made in a few cases in which the lines were so near to the reference line that the effect of a possible error in the value of the micrometer screw or in the adjustment of the grating would be small. In order to determine the value of the micrometer screw twenty measurements were made of the distance between E and b_1, this distance having been carefully ascertained by means of the circle. The space between these two lines was divided into two nearly equal parts which were separately measured, in order to bring the measurements into the centre of the field as nearly as possible. The resulting value of one division of the head of the micrometer screw was applied to the measurement of b_2, b_3 and b_4, referred to b_1 and also to D_2, referred to D_1. The extreme distance measured in this way was less than 11′ and it is evident from the investigation already given that the results will be free from error due to grating adjustment and also that they would be but little influenced by temperature although the latter correction has been applied.

RESULTS.

The following are the results of the angular measurements made upon what was presumed to be van der Willigen's. No. 16, for the purpose of ascertaining the relation of the grating to that of Mr. Peirce already referred to.

As the result of this series may possibly be of great value in the final adjustment of the absolute wave-lengths, it is thought proper to give all of the original measures, together with the temperature at which each was made, and the value of each when reduced to the standard temperature. The numbers will also serve to give an idea of the general accuracy of the angular measurements as well as of the sufficiency of the temperature corrections. It ought to be said, perhaps, that for the most accurate angular work this line is not well suited; a thinner line would undoubtedly give a more uniform series. But the fact that the line is easily seen, even under inferior optical power, is decidedly in its favor, as far as its general utility as a "reference line" goes. The measures were made in the spectra of the second order.

VAN DER WILLIGEN'S No. 16 (?)

Date	b observed	T	b reduced to 18°
December. 19	44° 57′ 35″.1	5°.9	44° 46′ 49″.0
,,	,, ,, 33″.5	6°.8	,, ,, 50″.7
,,	,, ,, 26″.	8°.6	,, ,, 50″.2
,,	,, ,, 20″.	10°.15	,, ,, 50″.1
,,	,, ,, 15″.2	11°.2	,, ,, 49″.3
,,	,, ,, 12″.7	12°.2	,, ,, 50″.6
,,	,, ,, 6″.5	13°.8	,, ,, 50″.5
,,	,, ,, 1″.3	15°.	,, ,, 49″.9
,,	44° 56′ 49″.9	18°.5	,, ,, 51″.8
,,	,, ,, 49″.2	18°.3	,, ,, 50″.3
,,	,, ,, 49″.2	18°.1	,, ,, 49″.6
,,	,, ,, 50″.5	17°.9	,, ,, 50″.1
,,	,, ,, 53″	17°.4	,, ,, 50″.7
,,	,, ,, 52″.8	17°.3	,, ,, 50″.1
,,	,, ,, 55″.8	16°.9	,, ,, 51″.6
Dec. 20	44° 56′ 50″.6	18°.3	44° 56′ 51″.7
,,	,, ,, 50″.5	18°	,, ,, 50″.5
,,	,, ,, 51″.2	17°.7	,, ,, 50″.1
,,	,, ,, 53″.8	17°.4	,, ,, 51″.5
,,	,, ,, 54″.6	17°	,, ,, 50″.8
,,	,, ,, 54″.6	16°.7	,, ,, 49″.6
,,	,, ,, 56″.3	16°.5	,, ,, 50″.6
Dec. 21	44° 57′ 33″.6	6°.5	44° 56′ 49″.8
,,	,, ,, 24″.5	8°.9	,, ,, 49″.5
,,	,, ,, 18″.6	10°.6	,, ,, 50″.4
,,	,, ,, 11″.	12°.3	,, ,, 49″.3
,,	,, ,, 10″.2	13°	,, ,, 51″.2
,,	,, 56′ 56″.5	16°.3	,, ,, 50.″
,,	,, ,, 57″.1	16°.4	,, ,, 51″
,,	,, ,, 56″.6	16°.4	,, ,, 50″.5
,,	,, ,, 52″.6	17°.2	,, ,, 49″.6

Between the date of the last observation and the next to be recorded the spectrometer was used for prism work and in consequence the grating had been removed, and an entire new adjustment in every particular had been made. The close agreement of the following three observations with those preceding furnishes strong evidence of their freedom from any constant error due to adjustments.

Date	b observed	T	b reduced to 18°.
Dec. 27	44° 57′ 0″.3	15°.5	44° 56′ 50″.8
,,	,, 56′ 59″.1	15°.5	,, ,, 49″.6
,,	,, 57′ 1″	15°.3	,, ,, 50″.7

Mean of 34 measurements.

$b = 44° 56′ 50″.35 \pm 0″.08$

B

Among the various values for the wave-length of this line, published by different authorities, are several that differ so widely from the others that it seems difficult to account for the discordance in any other way than by assuming that different lines have been measured in different cases. This region of the spectrum abounds in absorption lines and mistakes might easily be made in the selection of the proper line. In the present instance the line selected is believed to be that upon which Angström made his measurements. It is a line, somewhat darker and more prominent than the others, on the edge of the group in the direction of least wave-length, as is indicated in his map. A very fine line is often visible, still further in the same direction and distant from B something less than one unit of wave-length.

This is the only line in the series in which all of the measurements were made in any other than the spectrum of the second order. The first order was preferred in this case on account of the faintness of this part of the spectrum on one side of the normal to the grating.

Date	No. of obs.	Value of b	λ
Dec. 1.	4	27° 52′ 34″.4	6866.84
,,	3	,, ,, 34″.3	,, .83
,,	3	,, ,, 34″.7	,, .86
Dec. 2.	4	,, ,, 33″.8	,, .80
,,	4	,, ,, 33″.7	,, .79
,,	3	,, ,, 34″.4	,, .84

Mean of 21 observations.

$\lambda = 6866.82$

C

This line is broad and in preference to attempting to set upon the middle of the line in every instance, the edge of the line was selected and the results

afterwards reduced to the middle by means of a micrometric measurement of the width of the line.

Date	No. of obs.	Value of b	λ
Nov. 30	4	63° 19′ 28″.5	6561.64
,,	3	,, ,, 29″.3	,, .65
,,	3	,, ,, 27″.	,, .61
,,	3	,, ,, 26″.	,, .60
,,	3	,, ,, 27″.	,, .61
	4	,, ,, 26″.6	,, .61

Mean of 20 observations—

$$\lambda = 6561.62$$

Another series of 13 measurements was made in the spectrum of the first order, in which the line is more neatly defined and the set was made upon the middle of the line. The mean of the results agrees almost exactly with the preceding being

$$\lambda = 6561.61$$

D_1 and D_2

These lines are of such frequent use in wave-length measurements as furnishing, in the distance which separates them, a sort of unit of comparison, that it was thought advisable to make a more extended series of measurements upon them than upon any of the others. D_1 which is that of greatest wave-length, was measured directly but the wave-length D_2 was determined by means of micrometer measures from D_1.

D_1

Date	No. of obs.	value of b	λ
Nov. 18	8	53° 23′ 37″.6	5894.79
,, 19	5	,, ,, 36″.6	,, .77
,, 21	3	,, ,, 37″	,, .78
,, ,,	3	,, ,, 37″.6	,, .79
,, ,,	3	,, ,, 37″.6	,, .79
,, ,,	3	,, ,, 36″.7	,, .77
,, ,,	3	,, ,, 36″.8	,, .78
,, 22	3	,, ,, 37″.2	,, .78
,, ,,	3	,, ,, 37″.7	,, .79
,, ,,	3	,, ,, 37″.2	,, .78
,, ,,	3	,, ,, 36″.2	,, .76

Mean of 40 observations—

$$\lambda = 5894.780$$

D_2

Forty measurements were made with the micrometer for the distance of D_2 from D_1. The lines are too wide for very exact measurements but the distance between their centres thus obtained is doubtless sufficiently exact.

It is

$$\delta = 4' 46''.8 \pm 0''.2$$

from which we have

$$b = 53°18' 50''.3$$

and $$\lambda = 5888.68$$

From these results it appears that

$$D_1 - D_2 = 6.10$$

According to some previous measurements already referred to this quantity is as follows:

Mascart	6.3
Ditscheiner	6.4
van der Willigen	6.14

Angström furnishes two results differing slightly from each other. From his tables of wave-lengths it appears that the distance between these lines is 6.01, but on another page of his memoir he determines the wave-lengths of the two lines according to what he calls the "method of coincidences" and from those values we have,

$$D_1 - D_2 = 6.08$$

These last numbers he evidently considers the most accurate for he adopts their mean for his wave-length of D in his final table of "definitive values". The result given above differs very little, therefore, from what may be accepted as Angström's best measurements. It is impossible, of course, that any error will be found to exist in the grating space which will affect this result in the second decimal place: but a small error in that figure may exist consequent upon errors in the micrometric measures.

E

This is a double, one line being due to iron and the other to calcium and iron. The measurements were made upon the latter, which is that of the greatest wave-length. It was upon the E line that Angstrom made his most careful measurements and he presents in full, in his memoir, the series of 35 observations. But these appear to have been made upon the mean of the two lines, at least the result is exactly the mean of the wave-lengths of the two lines given in his table and in his series of micrometric measures values differing slightly from these are assumed. It is a little difficult to understand how accurate angular measures could be made upon the mean of two lines, or, at least, why one of them should not have been selected, provided there was sufficient dispersive power to separate them, which must certainly have been the case. It is worth noticing that the wave-length obtained by Angström for the mean of these lines agrees precisely with that of the line of greatest wave-length as determined by the following measures.

Date	No. of Obs.	Value of b.	λ
Nov. 26	3	45° 51′ 9″.1	5269.13
„ „	3	„ „ 8″.1	„ .10
Nov. 27	4	„ „ 9″.8	„ .14
„ „	3	„ „ 9″.8	„ .14
„ „	3	„ „ 9″.5	„ .14
„ „	3	„ „ 9″.4	„ .13
„ „	3	„ „ 9″.1	„ .13

Mean of 22 observation.—

$$\lambda = 5269.13$$

b_1 b_2 b_3 and b_4

As regards these lines the nomenclature of Angström's table and map has been followed. According to Angström and Thalen, b_1 and b_2 are to be attributed to magnesium, b_3 to nickel and iron and b_4 to magnesium and iron.

The first, b_1, is a broad line or band but near the edge towards the blue is a narrow, well defined line upon which the setting was made. The distance from b_1 to E being less than 1° the position of the line was determined in reference to E the measures being made, however, with the circle and not with the micrometer. It is believed that no error existed in the adjustment of the grating of sufficient magnitude to influence the results, especially as the grating was readjusted several times during the measurements.

b_1

Date	No. of Obs.	Value of b	λ
Dec. 7	7	44° 53′ 21″.6	5182.40
„ „	4	„ „ 21″	„ .39
Dec. 8	4	„ „ 21″.4	„ .40
„ „	3	„ „ 21″.1	„ .39
„ „	3	„ „ 21″.6	„ .40

Mean of 21 observations.—

$$\lambda = 5182.40$$

The remaining three lines of this group b_2, b_3 and b_4 were measured micrometrically, by referring them to b_1. Twenty measures were made on each line with the following results;—

line	value of b	λ
b_2	44° 46′ 8″.9	5171.47
b_3	44° 43′ 40″.8	5167.73
b_4	44° 42′ 38″.6	5166.16

One of the objects in measuring the lines in this group was to verify their distances from each other that they might be used as standards of comparison in that part of the spectrum, as the D lines are so frequently. In one or two instances, in well known works on spectrum analysis, the mistake has been made of applying the D lines as a unit of measure in the violet end of the spectrum and failing to consider the abnormal extension of that end of the prismatic spectrum. The use of the b lines may prevent so great an error as well as be exceedingly convenient on account of their prominence and the convenient portion of the spectrum in which they are found. For their differences of wavelength we have the following:

$$b_1 - b_2 = 10.93$$
$$b_2 - b_3 = 3.74$$
$$b_3 - b_4 = 1.59$$

From Angstroms results the same measures appear as follows;

$$b_1 - b_2 = 10.94$$
$$b_2 - b_3 = 3.68$$
$$b_3 - b_4 = 1.60$$

and the two series agree exceedingly well.

F

The following are the results of the measures upon the F line.

Date	No. of Obs.	Value of b	λ
Dec. 4	4	41° 26′ 30″.1	4860.17
.. ,,	3	,, ,, 29″	,, .14
,, ,,	3	,, ,, 29″.3	,, .15
,, 5	3	,, ,, 30″.1	,, .17
,, ,,	3	,, ,, 30″.3	,, .17
,, ,,	4	,, ,, 29″.8	,, .16

Mean of 20 observations

$$\lambda = 4860.16$$

G

Owing to the inferiority of the spectrum on the west side of the normal, which has already been discussed, this line could not be seen there with sufficient distinctness to make direct measurement desirable. The construction of the instrument rendered it impossible to work upon it in the spectrum of the first order, and, as it was but little more than 5° from F in the second order it was thought that the most accurate determination would be made by referring it to that line which was accordingly done. It is recognized, of course, that errors in grating adjustment, which will influence the results of this measurement by an amount proportional to the difference of the secants of the two angles, are of greater importance here than in any other instance; but this difference is still small and the error must be greater than is supposed to have existed in any case in order to produce a sensible effect. Besides, this adjustment was made five or six times during the measurement and the influence of accidental errors must be eliminated to a great extent. The uniformity of the results proves that such errors must have been extremely small.—The following are the results.

Date	No. of Obs.	Value of b	λ
Dec. 6	6	35° 54′ 46″.2	4307.19
,, 7	4	,, ,, 47″.4	,, .23
,, ,,	4	,, ,, 45″.6	,, .18
,, ,,	3	,, ,, 45″.7	,, .18
,, ,,	4	,, ,, 45″.6	,, .18

Mean of 21 observations

$$\lambda = 4307.19$$

RESUMÉ.

Below are given the collected results of these observations. In the second column will be found the corresponding wave-lengths according to Angström and in the third their differences.

	M	A	A—M
B	6866.82	6867.0	.18
C	6561.62	6562.1	.48
D_1	5894.78	5895.17	.39
D_2	5888.68	5889.09	.41
E	5269.13	5269.59	.46
b_1	5182.40	5183.10	.70
b_2	5171.47	5172.16	.69
b_3	5167.73	5168.48	.75
b_4	5166.16	5166.88	.72
F	4860.16	4860.72	.56
G	4307.19	4307.25	.06

It will be seen that the difference in no case amounts to a whole unit. Much of it, indeed, might be destroyed, by a more accurate knowledge of the grating space in each case. It will be observed that a sudden increase in the differences occurs when the group of b lines is reached. I think this finds an explanation in the fact, referred to in giving the observations on b_1, that the setting was made upon what appeared to be a well defined part of the line, *towards the side of least wave length*. As the other three lines are referred to this, it is to be expected that all will be affected alike and this is the case. It seems likely that Angström set upon the middle of the line. The part of the line referred to in these observations seems so well defined that I prefer to retain that as the point of departure rather than to reduce to the middle of the line, although the uniformity of differences would be greatly increased by such a reduction. I know of no reason for the small difference in the results for G, other than the difficulty of making measurements in that part of the spectrum which would doubtless affect both sets of observations more or less. If Angström had used the same part of b_1 for a point of reference that has been adopted here, I am convinced that for all of that portion of the spectrum in which the best measurements are possible, the series of differences would have been very nearly uniform and easily accounted for by an inconsistancy in the determinations of the grating space. As before stated, the ratios of these numbers ought to be independent of the value of the grating space and in order that a comparison may be made upon that basis, ratios have been computed for both series, using the value of D_1 as a unit. They are as follows.

RATIOS

$D_1 = 1$

	M	A	A—M
B	1.16490	1.16485	—.00005
C	1.11312	1.11313	.00001
D_1	1.	1.	0
D_2	.998965	.998965	0
E	.893864	.893882	.000018
b_1	.879151	.879212	.000061
b_2	.877297	.877355	.000058
b_3	.876662	.876731	.000069
b_4	.876396	.876460	.000064
F	.824485	.824526	.000041
G	.730679	.730640	.000061

The agreement here is sufficiently close, it seems to me, to justify the assertion that any other wave-length measurements that differ widely or irregularly from these must be incorrect.

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EARTHQUAKE MEASUREMENT

BY

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Professor of Mechanical Engineering and Physics in the University of Tôkiô,
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PREFACE.

The following Memoir has grown out of work which, with the generous assistance of the President of the University, I began in the winter of 1879-80, and which has been continued until now. The erection of instruments adapted to the absolute measurement of earthquake motions was quickly followed by the registration of numerous earthquakes. These occur in Tokio with a frequency which gives resident students of seismic phenomena an advantage difficult to overrate; and it is therefore no wonder that the instrumental side of Seismology has had its most considerable development in Japan.

The essay is chiefly an account of my own instruments, methods, and results; but, with the view of making it as complete a treatise on Earthquake Measurement as the present state of the subject allows, I have included many notices of apparatus designed by other contemporary workers, as well as of older forms. In referring to the work of other observers, I have endeavoured in every case to give the fullest credit for novelty, where there is novelty. It may be added, with respect to recent seismological work accomplished in Japan, that the five volumes of the Seismological Society's Transactions now published contain original accounts of most of the instruments described in this paper, and should be referred to by any one interested in the history of the subject.

My special acknowledgments are due to Mr. Kato, the President of the University, to Mr. Hamao, the former Vice-President, and to Mr. Hattori, the present holder of that office, for providing me with the means of establishing a Seismological Observatory. The frequency and success with which earthquakes have been recorded are in great measure owing to the attention bestowed on the instruments by my assistant, Mr. K. Sekiya, in whose care I am happy to be able to leave the apparatus on my approaching departure from Japan. To Mr. Fukuda I am indebted for the preparation of most of the Plates which give illustrations of the seismographs I have used. Plates XII-XX are exact copies of actual earthquake records, executed with a fidelity which does great credit to the draughtsman, Mr. Suzuki.

J. A. EWING.

The University, Tokio,
May 2nd, 1883.

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INTRODUCTION.

Any sudden mechanical disturbance occurring within or on the surface of the earth sets up a state of elastic vibration in the substance of the crust, which is propagated with diminishing intensity throughout the neighbourhood of the source, in the form of waves of compression, or distortion, or both. This motion constitutes an earthquake.

The disturbance may also produce, as a secondary result, gravitation waves in the water of seas or lakes. These admit of easy measurement by means of an ordinary tide-gauge; and in the present paper we have to do only with those vibrations which owe their diffusion to the rigidity and compressibility of the solid, or the compressibility of the fluid portions of the earth's crust.

The name earthquake might fairly be applied to all elastic vibrations in sea or land, without reference to their origin, whether that be the crumpling, tearing, or slipping of strata, the eruption of a volcano, the collapse of a subterranean cavity, the explosion of a mine, the rumbling of a carriage, the tread of a foot, or any one of the thousand other events which might be named as causes of a sudden disturbance of equilibrium. A reasonable but not strictly definable limitation restricts the use of the term to those comparatively large motions which extend over a considerable area, and whose immediate causes are natural and, in general, somewhat obscure.

The comparative suddenness of the movements to which the name earthquake is applied serves to distinguish them from other much more gradual elastic disturbances which are continually taking place in the earth's crust. It may be asserted with confidence that tidal deformations of the solid substance of the earth are caused by the varying attraction of the moon and sun, although their presence cannot be actually observed because they are masked by other and irregular movements of the same or a higher order of magnitude. The existence of these has been demonstrated by the remarkable experiments which Messrs. George and Horace Darwin have carried out at the instance of a committee appointed by the British Association for the purpose of investigating the lunar disturbance of gravity. Their observations show that even when tremors due to local traffic are eliminated, the solid ground is never really at rest. An increase of air pressure over any district causes there a dimple or elastic depression of the soil, while a relaxation of pressure allows the earth's surface to bulge upwards. The changing load due to the heaping up and withdrawal of water by tidal action makes the ground beneath sink and rise. Other more superficial strains

in the soil are caused by alternations of wet weather with drought, and by the absorption and radiation of solar heat. These and perhaps other causes combine to produce an incessant yielding of the earth's crust, so considerable and at the same time so irregular that the attempt to distinguish in it a periodic part directly due to lunar attraction has been abandoned as hopeless.

Although the movements just described are due to the elasticity of the earth, it would be a misnomer to call them earthquakes. The far more rapid tremors caused by a sudden mechanical disturbance are easily distinguishable from them, and require wholly different appliances for their detection and measurement.

After freely applying the restrictions which have been indicated, we are left with an immense number of disturbances to which the name earthquake is practically applicable. Their magnitudes vary within the widest possible limits, from the scarcely perceptible movements familiar to all residents in an earthquake country, to the convulsions which have destroyed cities and changed the face of a continent. From these, in some form, no part of the earth's surface is entirely exempt, and in certain favourable districts they occur with almost daily frequency.

Earthquake Measurement, the subject of the present paper, consists in determining as fully and exactly as possible the character of the motions which make up an earthquake. If this determination could be pushed back so far as to include the initial motions of the portions first disturbed, it would involve discovery of the originating impulse. It cannot be said that this result has hitherto been achieved, except in a very partial degree; and our knowledge of the origin of earthquakes consists chiefly of deductions as to what may be expected to result from the earth's gradual approach to a state of thermal and mechanical equilibrium, along with inferences from what geology tells about ancient and contemporary disturbances of the crust. This department of Seismology lies outside the scope of the present paper. It has been developed in a masterly manner by Hopkins in his Report to the British Association on the Geological Theories of Elevation and Earthquakes.* In the same paper he has applied the theory of waves in an elastic solid to the case of terrestrial disturbances. A brief restatement of the latter part of the theory of earthquakes will not be out of place here, since it both teaches the earthquake observer what to look for and guides him in the interpretation of his results. It will accordingly be found in Chapter I; after which instruments for earthquake measurement will be described, and the results of actual observations be stated and examined.

* British Association Report for 1847, pp. 33-92.

CHAPTER I.

THEORETICAL CONSIDERATIONS REGARDING EARTHQUAKE MOTION.

§ 1. *Vibrations proceeding from a centre within an elastic substance.*

When a single sudden disturbance of the most general character occurs at any place in an indefinitely extended homogeneous isotropic elastic solid, two waves or states of vibratory motion will proceed outwards along straight lines from the origin, with two different velocities. If the space in which the disturbance originates is very small compared with that into which the waves subsequently diverge, we may without sensible error consider the wave-fronts as spherical surfaces having the origin for centre. By wave-front is meant any surface forming the *locus* of particles which are simultaneously moving in the same phase. The line of transit, or direction along which each wave travels, is normal to the wave-front. One of the two waves consists of compression and dilatation of the material in the direction of the line of transit. This, which is propagated with the higher velocity of the two, is called the Normal wave: its passage causes each particle to move in the direction of the line of transit of the wave. The other wave, which travels more slowly, consists of distortion of the material unaccompanied by any change of volume. It is called the Transverse wave, and its passage causes each particle to move at right angles to the line of transit of the wave. The path in which a particle moves must be rectilinear so far as the normal wave is concerned; but the transverse wave may give rise to motion in any curve lying in the plane tangent to the wave-front. In neither case is it necessary that the path should be closed. This will happen only when the originating disturbance is cyclic: more generally a particle will be found permanently displaced from its initial position after the wave has passed.

We can easily imagine an originating impulse of such a character as would give rise to either wave alone, but in general both waves will be produced. Again, the properties of the disturbed medium may be such that one or other wave is impossible: thus a transverse wave cannot be generated in or transmitted by fluids owing to their want of elasticity of form; on the other hand an incompressible medium cannot be the seat of normal waves. The transmission of sound by the air illustrates the existence of normal waves in a substance capable of them only; while the transmission of radiant energy by transverse waves in the luminiferous ether exemplifies the other case.

§ 2. *Velocities of Transit.*

The velocity of transit of a wave through an elastic substance is

$$\sqrt{\frac{M}{\rho}},$$

where ρ is the density of the material and M is the modulus of elasticity for the particular kind of strain of which the wave consists. For transverse waves in an isotropic solid M is the modulus of rigidity, which, following the notation of Thomson and Tait (Nat. Phil. Chap. VII.), we shall denote by n. The strain involved in the transmission of the normal wave consists in the compression and expansion of spherical shells. At any point not near the origin, this approximates very closely to simple longitudinal strain (extension or compression in one direction without change of lateral dimensions). For this the modulus is $k + \frac{4}{3}n$, where k is the modulus of volume elasticity, or reciprocal of the cubic compressibility, and n has the same meaning as before. The quantities n and k have no ascertained relation to each other, and must be separately determined by experiment for any given substance.

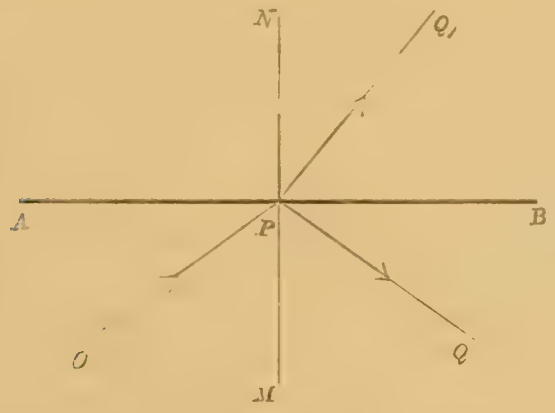
As both k and n are essentially positive the modulus for the normal wave is the greater of the two, and hence the normal wave always travels faster than the transverse wave, the ratio of their velocities being $\frac{1 \; k \; + \; \frac{4}{3} \; n}{1 \; n}$. The two waves will become more and more separated the farther they spread.

When, as will often be the case, the originating impulse is not single but consists of a number of successive displacements, there will be two groups of waves, normal and transverse. Each group will spread in the form of a spherical shell whose thickness is equal to the velocity of propagation of the corresponding type of waves multiplied by the time during which the originating disturbance has lasted. At a sufficient distance from the origin these two groups will, on account of their different velocities of propagation, be completely separated; and a particle there will make first a series of oscillations in the direction of the line of transit of the wave, and immediately afterwards a second series in directions perpendicular to the first. A particle more distant from the origin will experience two corresponding sets of movements with an interval of rest between them. On the other hand, at points nearer the origin the two groups will be more or less superposed, but the initial displacement of a particle anywhere will be along the line of transit, provided that any normal wave is transmitted whose origination did not occur later than that of the earliest transverse wave. The initial movement may be either away from or towards the origin, according to whether the initial strain there is one of compression or dilatation. Provided that none of the displacements are large and the medium is perfectly elastic, the speed of transit of all the separate waves in each group will be the same.

§ 3. *Effect of boundaries. Reflection and Reflection.*

When a wave, whether normal or transverse, meets a surface separating the medium in which it is travelling from another medium, it will in general suffer reflection and refraction. The lines of transit of the reflected and refracted waves will lie in the plane which contains the line of transit of the incident wave and the normal to the separating surface.

The simplest case is that in which both media are fluid, and consequently the incident, the reflected and the refracted waves are all of the normal type. In the figure, let AB be the bounding surface between two fluid media, and OP the direction of propagation of the incident wave. MN is drawn normal to the surface AB.



A wave is reflected back into the first medium along the line PQ, and another wave is transmitted into the second medium along a certain line PQ_1. The angle OPM or θ is called the angle of incidence, Q_1PN or θ_1 is called the angle of refraction and QPM the angle of reflection. QPM is equal to OPM, while θ_1 and θ are connected by the equation

$$\frac{V}{\sin\theta} = \frac{V_1}{\sin\theta_1},$$

where V is the velocity of transit of the incident wave, and V_1 is the velocity of transit of the wave transmitted into the second medium.

In the case represented in the figure V_1 is less than V, and there will be a refracted wave whatever be the angle of incidence. If the velocity in the second medium were the greater of the two, the refracted wave would be bent away from instead of towards the normal, and by increasing the angle of incidence sufficiently we should have PQ_1 coinciding with PB. This would occur when $\theta = \sin^{-1}\frac{V}{V_1}$. At this or any greater angle of incidence total reflection would take place; the incident wave would be restored to the lower medium without loss of energy, and with no other change than a change of direction and a change of phase.

In the more general case, when a refracted as well as a reflected wave exists, if we call the amplitude of displacement in the incident wave unity, the amplitude of the reflected wave is

$$\frac{\frac{\rho_1}{\rho} - \frac{\cot\theta_1}{\cot\theta}}{\frac{\rho_1}{\rho} + \frac{\cot\theta_1}{\cot\theta}},$$

where ρ and ρ_1 are the densities of the first and second medium respectively.* Also the amplitude of the refracted wave is

$$\frac{\frac{2\sin\theta}{\sin\theta_1}}{\frac{\rho_1}{\rho} + \frac{\cot\theta_1}{\cot\theta}}$$

For $\frac{\sin\theta}{\sin\theta_1}$ we may write $\frac{V}{V_1}$, and

$$\frac{\cot\theta_1}{\cot\theta} = \frac{V}{V_1}\sqrt{1-\left(\frac{V_1^2}{V^2}-1\right)\tan^2\theta}.$$

§ 4. *Example: Case of an Earthquake reflected at the surface of a sea or lake.*

Observations of the velocity of sound have shown that the speed of transit of elastic waves is about 1435 metres per second in fresh water, and about 332 metres per second in air. Hence $\frac{V}{V_1}$ for an earthquake reaching the upper surface of a sheet of water is 4.3, and

$$\frac{\cot\theta_1}{\cot\theta} = 4.3\sqrt{1+0.947\tan^2\theta}.$$

The ratio of densities $\frac{\rho_1}{\rho}$ is about 0.0013. These data give for the ratio of the amplitude of the reflected wave to the amplitude of the incident wave the value

$$\frac{1 - 3300\sqrt{1+0.947\tan^2\theta}}{1 + 3300\sqrt{1+0.947\tan^2\theta}}.$$

By writing this

$$\frac{2}{1 + 3300\sqrt{1+0.947\tan^2\theta}} - 1,$$

we see at once that the amplitude of the reflected wave is a minimum when the path of the incident wave is perpendicular to the boundary, and increases to unity as the angle of incidence approaches 90°. Even in perpendicular incidence, however, the reflected wave has an amplitude of 0.9994, that of the incident wave being unity. From this, and from the fact that the energy of the two waves is as the square of their amplitudes, it appears that an earthquake is in all cases reflected from the free surface of water with exceedingly little loss.

* See Green's Mathematical Papers, p. 238, or Lord Rayleigh's "Sound", § 270.

The amplitude of the wave transmitted into the air is

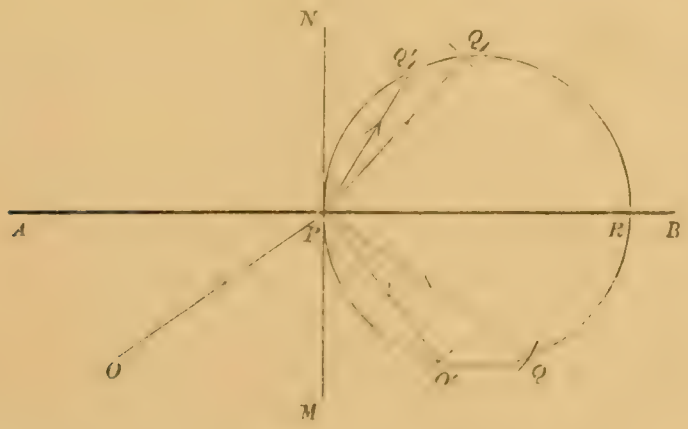
$$\frac{8.6}{0.0013 + 4.3\sqrt{1 + 0.947\tan^2\theta}},$$

which is a maximum (equal to 2 very nearly) when the wave strikes the boundary normally, and diminishes to zero as θ is increased to 90°.

The example will serve to show how, on account of the great difference in density and elasticity of the two mediums, while an earthquake is almost perfectly reflected when it reaches the atmosphere, it nevertheless may cause aerial vibrations of considerable magnitude, which, if the waves follow each other with sufficient frequency, will be perceived as sound.

§ 5. *Reflection and Refraction at the boundary of two solid mediums.*

The changes which elastic vibrations undergo at the surface of separation of two solid substances are of a more complex kind than those described above. The incident wave may be of either the normal or the transverse type. In either case there will, generally, be two reflected and two refracted waves, one of each pair being normal and the other transverse. The relation of velocity and direction is most simply expressed by saying that the velocity with which the trace of each of the five waves (one incident, two reflected, and two refracted) moves over the plane of separation of the mediums must be the same for all. The velocity of the trace is the velocity of the wave divided by the sine of the angle which the line of transit makes with the perpendicular to the boundary, and hence $\frac{V}{\sin\theta}$ has the same value for every one of the five waves concerned. In the figure, let OP be as before the direction of incidence, AB the boundary and MN perpendicular to it. From P set off a distance PR equal, on any convenient scale, to the velocity of transit of the incident wave divided by the sine of the angle of incidence. On PR as diameter describe a circle. From P as centre describe arcs with radii equal



successively to the velocity of (1) normal waves in the first medium, (2) transverse waves in the first medium, (3) normal waves in the second medium, (4) transverse waves in the second medium. Let these arcs cut the circle in Q, Q', Q_1, and Q_1' respectively. Then PQ, PQ', PQ_1, and PQ_1' represent in direction as well as in velocity of transit the four waves which result from the incident wave OP. In the figure the incident wave has been assumed to be of the normal type: the same construction with a different length of PR will apply to determine the disturbances produced by the incidence of a transverse wave.

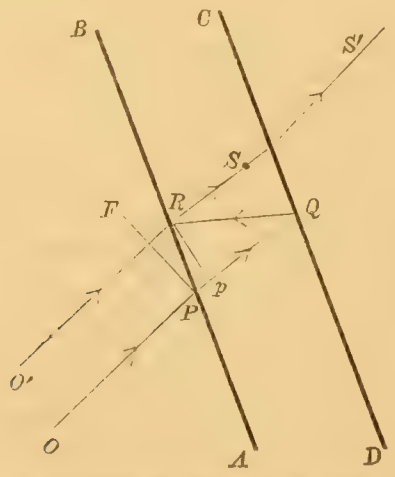
In special cases the system of waves which proceeds from the boundary will be less complicated: thus, in the case of perpendicular incidence, each incident wave will give rise to only one refracted and one reflected wave, both of the same type as the first. And, generally, any transverse wave in which the displacements are at right angles to the plane of incidence will be refracted and reflected as a transverse wave only.

§ 6. *Waves originating in or transmitted into an æolotropic solid.*

When the medium in which the disturbance originates is æolotropic with respect to its elasticity three different modes of vibration will in general be set up, and propagated with three different velocities.* And consequently when waves, of whatever type, impinge on an æolotropic medium, each incident wave will in general cause three refracted waves to be transmitted in different directions and with different velocities.

§ 7. *Effect of a stratum in reduplicating waves.*

Let $ABCD$ be a stratum with plane parallel sides lying between two other mediums, in one of which (that on the left of the figure) a plane wave is advancing in the direction OP or $O'R$.



* Sir W. Thomson, Enc. Brit. Ninth Edition, Art. "Elasticity", Chap. XVII.

At any station S within the stratum or S' in the medium beyond, the first wave to arrive will be the direct result of the refraction of the incident wave at R. A little later a second wave will arrive, due to a different portion of the same original wave-front, which has struck the stratum at P, been partially reflected at Q and again partially reflected at R. The interval of time between the first wave and this one will be the time taken for the wave to travel in the stratum from p to Q and from Q to R, p (determined by drawing a perpendicular from R on PQ) being the point already reached in the line PQ by the wave-front PF when it strikes the stratum at R. And by extending the same construction it is obvious that a third wave will reach the observing station, after suffering four reflections, a fourth after suffering six reflections, and so on, the interval between the successive arrivals being the same as that stated above, namely

$$\tau = \frac{2\,PQ - Pp}{V_1},$$

where V_1 is the velocity of transit through the stratum.

We thus find at any point to the right of AB, as the result of a single incident wave, an indefinite series of waves of the same type, having the same direction, with a constant period τ and with amplitudes diminishing in a geometrical progression. Writing b for the perpendicular thickness of the stratum, and θ_1 for the angle which the waves in it make with the normal to its sides, we have $PQ = \frac{b}{\cos\theta_1}$ and $Pp = \frac{2b\sin^2\theta_1}{\cos\theta_1}$. Hence

$$\tau = \frac{2b\cos\theta_1}{V_1},$$

which is a maximum, equal to $\frac{2b}{V_1}$, when the path of the incident wave is perpendicular to the stratum. The amplitude of each wave is less than that of its predecessor in the ratio $n\,n' : 1$, where $n : 1$ is the ratio in which a wave in the stratum is reflected at CD, and $n' : 1$ is the ratio in which a wave in the stratum is reflected at AB.

As a simple example, take the case of a single wave of compression and dilatation ascending vertically through a sheet of still water of a uniform depth of 10 metres. A series of doubly reflected waves will follow the first at a uniform interval of $\frac{2\times 10}{1435}$ or $\frac{1}{72}$ of a second. The rate of decay of amplitude in the series will depend almost wholly on the degree of imperfection of the internal reflection at the bottom of the water, since reflection is almost perfect at the upper surface (§ 4). The ratio of the internally reflected to the incident wave at the bottom will be considerable provided that $\frac{\rho_1}{\rho}$ is not nearly equal to $\frac{V}{V_1}$ (§ 3), and in actual cases it will probably be about 4 : 5. In these conditions a continuous sound may be produced with rapidly diminishing loudness, and be audible for an

appreciable time. More commonly, however, the secondary vibrations due to double reflection in a stratum will have too long a period to give rise to a continuous sound.

If the sides of the stratum are not parallel, the period and also the direction of the secondary waves observed at any station in or beyond the stratum will change progressively, and a like effect will be produced even by a uniformly thick stratum when the front of the incident wave is not plane but curved. The figures given above illustrate these cases.

§ 8. *Effect of obstacles. Earthquake Shadows and Diffraction.*

When waves travelling through an otherwise homogeneous medium impinge upon a space occupied by matter whose mechanical properties (as to density, compressibility or rigidity) differ from the properties of the medium round it, the foreign body moves so as to act as a new source of disturbance, and secondary waves are thrown off from it in all directions. These are of course generated at the expense of the energy of the original system of waves.

When the dimensions of the foreign body are sufficiently increased, reflection and refraction take place at its surface according to the principles already stated. If we suppose it to be impervious to waves of the particular class which strike it, it will act as an obstacle to shield from disturbance a portion of the medium lying beyond it, and may therefore be said to cast an earthquake shadow.

The geometrical outlines of the earthquake shadow will of course be determined by drawing lines parallel to the direction of the incident waves and tangent to the sides of the obstacle: but neither will this region be completely shielded from disturbance nor will the surrounding portions of the medium be so intensely disturbed as they would be were the obstacle absent. In other words

there will in general be a great deal of diffraction: the limits of the shadow will be ill defined, and unless the obstacle is very large or the observing station very near it, a complete absence of disturbance will rarely be found. This is because of the comparatively great wave-length of earthquake vibrations: to cast a clearly defined shadow the dimensions of the obstacle measured transverse to the path of the incident ray must be great compared with the wave-length of the constituent vibrations—a condition difficult to find fulfilled when we are dealing with the long-period waves which make up an earthquake.

§ 9. *Energy of Vibrations.*

The energy which must be expended in producing an elastic wave, and which is carried by the wave as it spreads, depends amongst other things on the form of the wave—that is to say, on the relation of displacement to time during the passage of the disturbance. In a wave of the simple harmonic type, the energy per unit of area of wave front is

$$\frac{2\pi^2 \rho V a^2}{\tau},$$

where ρ is the mean density of the medium, V the velocity of transit, a the greatest displacement of a particle from its undisturbed position, and τ the period of the wave. When a spherical wave spreads in a uniform and perfectly elastic medium, its energy remains constant but is distributed over an area which increases with the square of the distance r from the origin, and since the other quantities are constant (except very near the source), the amplitude of vibration will diminish as the distance from the origin increases, or

$$a \propto r^{-1}.$$

When, however, the disturbance occurs in a stratum whose properties differ much from those of adjoining strata, so that little of the energy of the earthquake is transferred to them, and the vibrations spread nearly in one plane instead of spherically, the energy per unit of area of wave front will diminish nearly as the distance from the origin increases, and

$$a \propto r^{-\frac{1}{2}} \quad \text{approximately.}$$

There is some evidence that a disturbance occurring on the surface of the soil is in certain cases propagated to surrounding parts of the surface more nearly in this manner than by spherical distribution.

When reflection and refraction occur at the boundary of two mediums, the energy of the incident wave will be shared by the reflected and refracted waves without loss, except in the special case where the adhesion of the two mediums is insufficient to prevent relative sliding during the passage of the vibrations, when a portion of the energy will be dissipated by friction at the boundary. A similar dissipation will occur at a fissure in a single medium, if the parts separated by the fissure do not cohere firmly enough to prevent relative motion. Another cause of loss of energy by the principal waves of an earthquake is the heterogeneity of the vibrating medium, in which every local variation of mechanical

quality causes the places where such variations occur to be originators of secondary waves (§ 8).

§ 10. *Effect of Imperfect Elasticity.*

The fact that the elasticity of most of the substances which make up the earth's crust is imperfect operates powerfully to diminish the energy and therefore the amplitude of earthquake motions as the vibrations spread from the source, and consequently to limit the area throughout which any one disturbance is felt. The earthquake energy is expended in overcoming internal friction within the vibrating medium, and takes the form of heat. This internal friction is in general of two kinds: in one—the viscosity of fluids—the resistance to relative motion of adjoining parts depends essentially on the velocity of that motion, being, for low velocities, proportional to the velocity. The other is of a static character; it resembles the friction between solid bodies in being nearly independent of the velocity with which the changes of form take place, and, in any one substance, depends chiefly on the extent of the deformation. If we cause a viscous fluid to undergo a cyclic change of form or volume, an amount of energy will be dissipated which will be (approximately) proportional to the rapidity of the change, and will be zero if the change takes place infinitely slowly. If we perform the same operation with an imperfectly elastic solid, an amount of energy will be dissipated which will be nearly independent of the rate of deformation, and will not vanish when the change takes place infinitely slowly, but will be greater in proportion to the whole amount of work involved in the operation the greater the amplitude of deformation is, since the body's elasticity is more nearly perfect for small strains than for large ones.

The effect of viscosity on vibrations propagated by a fluid has been examined mathematically by Stokes*, who has shown that besides reducing the amplitude more rapidly than the spreading of the wave involves, it makes the velocity of propagation less than it would otherwise be. Both effects are greater for waves of short period than for waves of long period.

The writer is not acquainted with any investigation of the effect of imperfect elasticity on vibrations transmitted by solids. If, as appears probable, its effect is to reduce the velocity of propagation, as well as the amplitude, we should expect to find this reduction less for waves of small amplitude than for waves of large amplitude, since the strains involved in waves of small amplitude would lie within or nearer to the so-called limits of elasticity, inside of which the substance obeys Hooke's Law. And further, in a group of waves whose amplitudes were unequal, the tendency would be for those whose amplitudes were large to lose more energy than the others in proportion to their whole stock, and hence differences of amplitude would be reduced. Thus a series of waves originated by double reflections in passing through a stratum (§ 7) would tend to have

* On the Internal Friction of Fluids in Motion, etc. Cambridge Transactions, Vol. VIII: or Reprint of Papers, Vol. I, p. 101.

their amplitudes to some extent equalized by passing subsequently through a medium whose limits of elasticity were so narrow as to be exceeded by the strains the waves caused. The elasticity of the medium might however be nearly perfect with respect to the very minute vibrations which accompany or originally follow the principal shock, and these would therefore be transmitted with comparatively little loss, and (if the above conclusion is correct) with a velocity greater than that of the principal movements. Moreover, it appears probable that a medium such as clay or semi-solid mud will transmit vibrations of short period more nearly like a true solid, and vibrations of long period more nearly like a viscous liquid, and that the former will be propagated with greater velocity than the latter. It is a fact of common observation that the sound which in many cases accompanies an earthquake is usually heard before the arrival of the separately perceptible undulations of the soil; and the writer's observations have shown that the records given by seismographs frequently exhibit minute vibrations of short period at the beginning of earthquakes, either entirely preceding or superposed on the earliest principal movements, whose periods are longer and which continue to be traced after the short-period movements have died out.

§ 11. *Movements of a particle during an Earthquake.*

The actual constitution of the earth's crust is so far from being homogeneous, even on a large scale, that any disturbance propagated through it must be greatly modified by the numerous reflections, refractions, and diffractions which occur along its route. Even when a single impulse proceeds from a single originating point, it is obvious from what has been said above that in general many waves both of compression and of distortion will reach an observing station distant from the source, travelling in different lines. The direction of the principal normal impulse will not in general be that of a line joining the observing station with the source. Its line of transit will usually be bent in a vertical plane, both sharply by passage through surfaces which separate different strata, and gradually on account of continuous changes in the elasticity and density of a single stratum, produced, in the upper layers especially, by gravity and by the presence of moisture in the soil. And in many cases this bending will take place in a horizontal plane also, with the result that the azimuth of the principal normal displacement which occurs at a distant station will not coincide with the bearing of the origin.

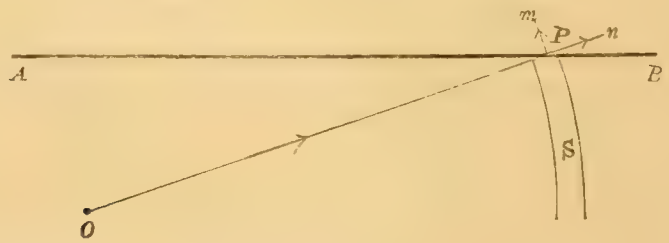
When, in addition to the considerations which have been indicated above, it is borne in mind that the place of origin of an earthquake may itself be widely extended (as, for example, in shocks which are caused by the formation of a fissure or "fault" of some length), and that each part of the initially disturbed region will generally originate not one but many successive impulses, it is clear that the movements which may be expected to occur at an observing station are complex to an almost indefinite degree.

To completely determine the motion of the ground at any one point we must observe, from the beginning to the end of the disturbance, the displacement

of a particle (measured from the position occupied before the disturbance began) both in magnitude and direction, in conjunction with the time. To this end it is usual, and for most purposes desirable, to treat each displacement as the resultant of three rectangular components, one vertical and two horizontal. If the relation of the displacements along three axes to the time be recorded, we possess complete information as to the movement of the ground at the observing station. By combining the records for three axes we may of course deduce the absolute direction of motion of a particle, its velocity, and its rate of acceleration at any instant during the earthquake; while by comparison of the records taken at one station with corresponding records taken at other stations it is (theoretically, and in a few cases practically) possible to determine the velocity and direction of propagation of the earthquake waves.

§ 12. *Motion at the surface of the soil due to a normal wave.*

At any point well within a uniform vibrating mass the direction of motion of a particle during the passage of a normal wave coincides with the line of transit of the wave (§ 1). But when a wave of compression and dilatation approaches a boundary of the medium in which it travels, in any other direction than perpendicular to the boundary, the movement of particles there will no longer coincide with the line of transit of the wave. If the neighbouring substance, from which the medium in question is separated by the boundary, differs from it in density or elasticity, the portions of the original medium which lie near the boundary will be either more or less free to expand and contract laterally during the passage of the wave than other portions. To take the important practical case, a portion of the soil at or close to the surface of the earth is more free to expand laterally when it is compressed by an obliquely incident normal wave, than other portions lying in the same wave front, and hence the strain at the surface caused by a plane wave (or spherically divergent wave from a distant source) will not be a simple longitudinal strain, but, since a state of compression coexists with a state of displacement away from the origin, the displacement of a surface particle during the passage of the phase of compression will be upwards as well as outwards along the normal to the wave. The direction of the particle's motion will therefore be more nearly vertical than the line of transit of the wave—a fact which prevents us from inferring the direction of transit from a knowledge of the direction in which a particle at the surface is initially displaced.



Thus in the figure, when the shell S is compressed by the passage of a normal wave whose source is at O, a particle P at the surface is displaced along Pm because of the lateral expansion of the soil, as well as along Pn; and again when the shell AB is dilated, the particle is displaced downwards as well as along PO, and hence its direction of oscillation lies between Pn and Pm.

§ 13. *Preliminary Statement of the Results of Observations.*

Automatic records given by seismographs confirm what has been said, on theoretical grounds, as to the complexity which earthquake motions may be expected to present. They show that, as observed at a station on the surface of the earth, an earthquake consists of a very large number of successive vibrations —in some cases as many as three hundred have been distinctly registered. These are irregular both in period and amplitude, and the amplitude does not exceed a few millimetres even when the earthquake is of sufficient severity to throw down chimneys and crack walls, while in many instances the greatest motion is no more than a fraction of a millimetre. The periods of the principal motions are usually from half a second to a second, but, as has been already said, the early part of the disturbance often contains vibrations of much greater frequency. The earthquake generally begins and always ends very gradually, and it is a noteworthy fact that there is in general no one motion standing out from the rest as greatly larger than those which precede and follow it. The direction of motion varies irregularly during the disturbance—so much so that in a protracted shock the horizontal movements at a single station occur in all possible azimuths. The duration, that is to say the time during which the shaking lasts at any one point, is rarely less than one minute, often two or three, and in one case in the writer's experience was as much as twelve minutes.

A more particular account of the actual results of earthquake measurement will be given in a later chapter. The facts just stated are deduced from the writer's observations, made at the University of Tokio, and they describe, in brief, the characteristics of the moderate earthquakes which occur with great frequency in the Plain of Yedo, occasionally with destructive effect, but much more commonly without doing any damage or attracting more than a momentary attention from the inhabitants. This outline statement of actual results has been presented here as affording data by which we may more readily discuss the practical value of various seismometers. Much time and labour has been wasted in seismometry through false preconceptions as to the character of earthquake motion. Many instruments have been constructed under the idea that an earthquake consists essentially of one relatively large impulse, easily distinguishable from any minor shakings which may accompany it. How far this may be true of great earthquakes, or of earthquakes in other localities, it is as yet impossible to say; nothing could be less true of the earthquakes we experience in Japan, whose frequency and manageable size make them good subjects for measurement.

CHAPTER II.

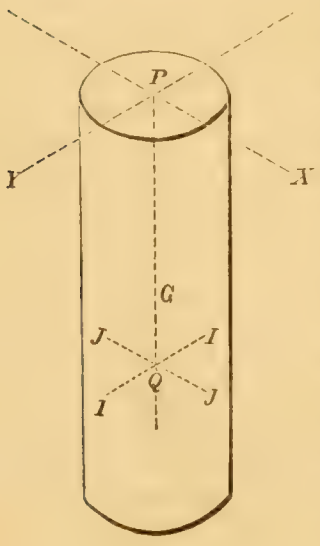
INSTRUMENTS FOR OBSERVING HORIZONTAL MOVEMENT:— THE HORIZONTAL PENDULUM SEISMOGRAPH.

§ 14. *Measurement of earthquake motions by reference to a Steady Point.*

Instruments designed for the measurement of earthquake motions aim, with few and unimportant exceptions, at giving a point which does not move during the disturbance, and which will therefore serve as a datum with respect to which the movements of the earth may be determined. No actual instrument gives a rigorously steady point throughout a prolonged disturbance, but certain devices which will now be described achieve the desired object nearly enough for practical purposes, and it is by them that our exact knowledge of earthquake motion, so far as we have any exact knowledge, has been gained.

§ 15. *Kinetic condition yielding a Steady Point.*

If any one point of a rigid body suffers a displacement in the line joining it with the centre of inertia of the body, the whole mass will share the same motion, which is then one of pure translation; but if the point suffers a small displacement in any direction at right angles to this line, the motion of the body will consist of rotation about an axis (called the Instantaneous Axis) which intersects the prolongation of the line joining the displaced point with the centre of inertia, and is perpendicular to the plane containing that line and the direction of displacement. Points situated in the instantaneous axis remain at rest, and all other particles of the body move through distances proportional to their distance from the instantaneous axis. Thus, in the figure, let the mass sketched, whose centre of inertia is at G, be pivotted at P. When P is moved in the direction GP or PG, all points of the mass are equally displaced: but when P moves through a small distance in any direction PX perpendicular to PG, the mass will revolve about a certain axis II, which is the instantaneous axis for the assumed (infinitesimally small) displacement. II is in the plane GPY, PY being drawn perpendicular to PX and PG,



and it cuts the line PO produced at a point Q such that

$$PQ = \frac{k^2}{PG},$$

where k is the radius of gyration of the mass about the axis PY. Q is called the centre of percussion relative to the axis PY.

If the mass has kinetic symmetry about the line PG, so that k has the same value for all axes passing through P and perpendicular to PG, then the instantaneous axis corresponding to any other displacement of P perpendicular to PG will also pass through Q. Thus, for example, a small displacement of P along PY will cause rotation of the mass about the axis JJ. In this case the point Q will (so far as its motion depends merely on the inertia of the mass) remain at rest during any small displacement of the point P in any direction in the plane XPY; and Q may therefore serve as a Steady Point by reference to which such displacements may be measured.

The fact that in earthquake motions the displacements of the pivotted point P are not infinitesimally small does not affect the result just stated to any practical extent; it is sufficient that the displacement should be small compared with the length OP—a condition easily satisfied in practice.

§ 16. *Static condition requisite for a Steady Point.*

If no forces acted on the mass other than those producing displacements of the pivotted point P, the statement of the last paragraph would be true without reservation—that any single small movement perpendicular to PG would leave a certain line in the mass at rest, and that in the case of a mass with kinetic symmetry about PG, a certain point Q would be left at rest whatever motions of P were caused to take place in the plane perpendicular to PG, provided these motions were small.

But in attempting to apply this principle to earthquake measurements we must take account of the existence of other forces which inevitably act on the pivotted mass, notably of gravity. Assuming the mass to be in equilibrium before a displacement of P occurs, it is obvious that, in order to the maintenance of Q as a steady point, the equilibrium must be *neutral* with respect to the displacements now under consideration. If it be unstable the displacement of P will cause an increasing disturbance of the mass as a whole. If it be stable the assumed displacement will cause oscillations which, if the displacement of P occurs periodically, may attain a magnitude so great as to deprive Q of all claim to be called a steady point.

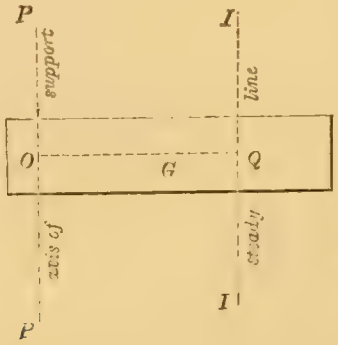
If, for example, the point P at which the (otherwise free) mass is pivotted be fixed to the surface of the earth, the mass may be placed in equilibrium in two positions—either as an inverted pendulum with G vertically above P, or as a common pendulum with G vertically below P. The former arrangement gives unstable equilibrium and is of course impracticable for seismometry without important modification. In the latter case the equilibrium is stable, and any hori-

zontal displacement of P will introduce a couple due to gravity, tending to make Q follow the movement of P. The pendulum swings, with the result that Q, far from remaining at rest, may sometimes acquire a movement much greater than that of P itself.

We shall see later that by combining a common with an inverted pendulum we may obtain a steady point in neutral equilibrium, capable of being used for the measurement of motions in any horizontal direction, and that the same result may be arrived at in other ways. To obtain a steady point with respect to movements in one direction only is, however, a simpler problem, the solution of which will be described first.

§ 17. *Horizontal Pendulum Seismometer.*

Instead of having only one point fixed, let the body be pivotted in such a manner that a certain line (say the line POP in the figure below) is constrained to remain at rest, freedom being left to rotate about this line. Further, let this fixed axis be vertical and attached to the earth's surface: the body then forms a horizontal pendulum.



Then if an earthquake movement occurs either vertically, or horizontally along OG, the pivotted mass simply suffers displacement as a whole. But if the ground moves through any small distance horizontally and perpendicular to OG, the mass rotates through a correspondingly small angle about the vertical axis II cutting OG produced in Q, so that $OQ = \frac{k^2}{OG}$ as before. More than this, the equilibrium of the mass being neutral, no unbalanced forces are brought into action by the change of position, and there is consequently no reason, static or kinetic, why the line II should move either during or after the displacement of the axis of support. It remains unaffected by the disturbance, and any point of it may be taken as a datum by reference to which the motion of neighbouring bodies fixed to the earth's surface may be determined.

To obtain a complete measurement of any horizontal motion of the ground, it is only necessary to use a pair of similarly pivotted and independent masses, which may most conveniently be set at right angles to each other, so that each

will give a steady point (or rather line) with respect to that component of the actual horizontal motion which causes bodily translation of the other.

We cannot, however, apply the same device, without an important addition which will be described in a later chapter, to the measurement of vertical motions, since for their registration the mass must be left free to move in the direction in which gravity acts.

§ 18. *Friction Error. Increase of Effective Inertia by the use of a second mass pivotted on the first at the Steady Line.*

In an actual instrument the friction at the joints by which the mass is pivotted on the line PP, and also at the recording index, when one is used to give a permanent trace of the disturbance, prevents the line II from remaining strictly at rest. The friction at the joints will tend to make the mass acquire during displacement less angular motion than is necessary to keep II at rest; and hence the practical instantaneous axis, which does remain unmoved, will lie farther away than II from the axis of support. Consequently a measurement based on the assumption that the line II is steady will err by being too small. Friction at the point of the recording index will introduce an error of the same kind. If these errors were uniform it would be easy to ascertain and allow for them, but they will in general vary in different movements and even in different parts of a single movement, since they depend on the ratio of the forces due to friction to the resistance which the pivotted mass offers to angular acceleration. Hence the friction error (with a given arrangement of joints and marking pointer) will be great when a displacement occurs slowly, but comparatively small in sudden disturbances, and practical experience has shown that in many cases earthquake movements are so slow as to make the elimination of considerable friction errors a matter of great difficulty. The effective inertia of the suspended mass must be increased, and, relatively to it, the friction reduced as far as possible.

The most effective position for the material of the pivotted mass is at the instantaneous axis, and accordingly we may improve the steadiness of the line II by pivotting there in neutral equilibrium a second mass or bob, free to turn about the line II, and therefore equivalent to an equal quantity of matter concentrated at that line itself. Moreover, the mass of the original body pivotted at PP (which is less advantageously distributed) may then be diminished as much as we please, or rather as much as is consistent with rigidity. In doing this, care must of course be taken to preserve the kinetic relation between the axes PP and II unchanged. And if the mass of the original pivotted body or frame, as we may now call it, since its function is merely to furnish an axis of support for the bob, be very small compared with the mass of the bob, a small error in the position of II will not affect the steadiness of that line sensibly. With this disposition of parts we secure the maximum of effective inertia for a given total mass and a given distance of the instantaneous axis from the axis of support.

§ 19. *Determination of the Effective Inertia and Steady Line.*

In estimating the effective inertia and steadiness of a system composed of a frame, or piece pivotted to the earth, and a bob, or piece pivotted to the frame at its corresponding steady axis (passing through the centre of percussion), it is convenient to remember that the frame is equivalent, kinetically as well as statically, to a pair of masses, one concentrated at the axis of support and the other at the centre of percussion.

Calling

M_f the mass of the frame;

M_b the mass of the bob;

r the distance of the centre of gravity of M_f from the axis of support;

r' the distance of the centre of percussion of the frame from the axis of support;

then M_f is equivalent to a mass $\frac{r}{r'} M$ at the centre of percussion, together with a mass $\left(1 - \frac{r}{r'}\right) M_f$ at the axis of support. Of these the former alone contributes to the steadiness of the system. The bob is equivalent to a particle of mass M_b concentrated at the axis about which it is free to turn on the frame; and the whole effective inertia (or in other words the mass referred to the steady line) is

$$M_b + \frac{r}{r'} M_f.$$

If instead of being pivotted the bob were fixed to the frame, we should require to treat the whole mass as "frame". The effect would be to shift the steady line outwards, since the moment of inertia of the system about the axis of support would be increased. The difference in general effect between a frame with pivotted bob and a frame consisting of supporting piece and bob rigidly connected is considerable if the transverse dimensions of the bob are comparable to its distance from the axis of support, and in that case we do well to pivot the bob; but when the bob is small and the horizontal length of the frame is great, pivotting the bob brings little advantage to counterbalance the complication of parts which it involves.

A convenient experimental way of finding the steady line of the frame is to hang it up vertically, with the ordinary axis of support placed horizontally. Then let it be swung through small arcs as a common pendulum, and its period (τ) measured. The equivalent simple pendulum is one whose length is r', the distance from the axis of support to the centre of percussion, and therefore

$$r' = \frac{g \tau^2}{4 \pi^2}.$$

§ 20. *Multiplication and Registry of the motion.*

In those earthquakes which both from their frequency and moderate character are best suited for registration, the actual motions are usually so small that to

obtain distinct indications we require some mechanical multiplication of the displacement of the ground relatively to the steady line or steady point. In the horizontal pendulum seismometer the simplest way to effect this multiplication is to make a portion of the frame (§ 18) consist of a light rod projecting to a considerable distance beyond II, and to use its end as a pointer which inscribes the record on a fixed or moving plate of smoked glass. Then when a small displacement of the axis of support PP takes place perpendicular to the plane of PGP, while II remains at rest, the marking point moves in the opposite direction through a distance equal to the displacement of the ground multiplied by

$$\frac{\text{Distance of Marking Point from Instantaneous Axis}}{\text{Distance of Instantaneous Axis from Axis of support.}}$$

But at the same time the plate on which the record is traced has been carried, along with other neighbouring objects on the earth's surface, in the direction of and by an amount equal to the displacement, and hence the length of the line traced on the smoked-glass plate is the sum of these two movements, and is equal to the actual displacement multiplied by

$$\frac{\text{Distance of Marking point from Axis of Support}}{\text{Distance of Instantaneous Axis from Axis of Support.}}$$

Or, more simply, we may conceive a displacement opposite to that of the ground to be superposed on the actual motion of every point. Then the axis II is to be taken as moving while objects fixed to the earth remain at rest, and it is at once evident that the above is the ratio of multiplication.

In the arrangement just described the pointer is rigidly attached to the frame, and must therefore be included as forming part of the frame in calculating or finding experimentally the position of the steady line.

§ 21. *Multiplication by an independent lever.*

Although in the horizontal pendulum seismograph a multiplied record is very conveniently got by using as multiplying lever the pivotted frame of the pendulum itself, it is frequently desirable in other instruments (and even in the horizontal pendulum, if the length of the pendulum is considerable) to magnify the motion by the use of an independent lever, pivotted to the ground, and having its short arm connected to some point in the suspended mass, while its long arm carries the tracing point.

In order that such a lever may not affect the steadiness of any seismometer to which it is applied, it should in strictness conform to the following conditions, the first static and the second kinetic:—(1) together with the suspended mass to which it is applied, it must form a system whose equilibrium is neutral; (2) its point of connection with the principal mass must be related to its own dimensions and point or axis of support in such a way that, when a disturbance of the ground takes place, no stress due to the inertia of the parts will be introduced between the multiplying lever and the principal mass at their point of connection. The simplest way of securing the second condition is to make the point of

connection the centre of percussion of both pieces; in other words, to make the multiplying lever touch, at its own centre of percussion, the steady point or steady line of the seismometer to which it is applied. If, however, we prefer to apply the multiplying lever elsewhere than at the steady point of the seismometer, we may still fulfil the kinetic condition rigorously, by arranging the points of support and of contact so as to satisfy to the following proportion:—Let P, as before, be the point of support and Q the steady point of the principal piece or seismometer proper; and let p be the point of attachment to the ground, and q the corresponding centre of percussion of the multiplying lever,—then the point of contact between them must occupy the same relative position with respect to p and q in the lever as it occupies with respect to P and Q in the principal piece.

In practice, however, we may avoid the necessity of considering precisely the static and kinetic qualities of the multiplying lever by simply making it so light, relatively to the principal steady mass, that its own weight and inertia do not sensibly affect the result. A practically far more important consideration in its construction is the friction of the marking point, whose bad effects increase with the ratio of multiplication, and which, unless proper steps are taken to reduce it, interferes very seriously with the correctness of the indications.

§ 22. *Record of successive displacements in conjunction with the time.*

To observe the numerous successive displacements which make up an earthquake, it is only necessary to give the surface on which the writing pointers trace their movements a continuous motion, the best direction for which is directly away from the pointer and at right angles to its expected displacement. In some instruments the surface to be written on is set in motion by means of the earthquake itself—the disturbance being caused to start a clock or other motor. This plan is subject to the disadvantage that at the beginning of the earthquake a portion of the disturbance, of uncertain length, occurs without leaving more than what may be called a *static* record. When the horizontal pendulum is used as a seismograph it is quite practicable, and for many reasons preferable, to keep the surface moving under the pointers continuously and uniformly by clock-work, in expectation that a shock may begin at any moment. A sheet of smooth glass, covered with a thin layer of soot by being held over the flame of a smoky lamp, forms a convenient surface for the reception of earthquake records. By making the pressure of the marking point on the glass no greater than is needed to break the film of lamp-black, the friction between it and the plate may be kept so small as to introduce almost no error; and, after an earthquake, permanent copies of the record may easily be got by varnishing the plate and using it as a "negative" from which to print photographs.

§ 23. *Actual Horizontal Pendulum Seismograph.*

A seismograph consisting of a pair of horizontal pendulums, which indicate two components of the horizontal motion of the earth, was designed by the writer

in 1880* according to the principles set forth in the above paragraphs, and has been since then in almost continuous use at the University of Tokio. Its construction will be readily understood by reference to Plate I, where fig. 1 gives an elevation and fig. 2 a plan of one of the horizontal pendulums, and fig. 3 shows in outline a plan of both and their position with respect to the moving glass plate. Each of the two precisely similar horizontal pendulums consists of a light but rigid brass frame *a*, a long pointer of straw *b*, and a solid cylindrical brass bob *c*. The frame *a* and pointer *b* are free to rotate together about a vertical axis *dd* (which is fixed to the earth and forms the axis of support), being pivotted by a conical steel point which works in a conical hole at the bottom, and by a conical hole at the top into which presses a set-screw carried by an inverted stirrup which is in one piece with the base-plate. In fig. 1, one side of this stirrup is, for the sake of clearness, supposed to be removed. The bob *c* is pivotted to the frame *a* in a similar manner, so as to be free to rotate about the axis *ee*. The pointer *b* is attached to the frame *a* at *f*, by a joint which allows it to rise and fall vertically, but not to move in a horizontal plane except along with *a*. The frame *a* and pointer *b* together are proportioned so that *ee* is the steady line (§ 17) relative to *dd* as axis of support. Hence when a small horizontal displacement of the ground occurs transverse to the lever, *ee* would (were it not for friction at the joints and at the marking pointer) remain stationary, even without the help of the bob *c*, and the inertia of the bob, pivotted as it is on the line *ee*, enormously increases the tendency of that line to keep steady. For these movements therefore the line *ee*, and indeed the bob as a whole, serves as a standard of rest, and they are recorded on a magnified scale on the smoked-glass plate *g*, which is lightly touched by a steel point at the end of the straw *b*. Horizontal movements parallel to the length of this lever leave it unaffected, but are recorded by the second lever, similar to the first, and set at right angles to it. The two are placed so that their marking points touch a circular glass plate *g* at different distances from its centre. By means of a clock

* See Proc. Royal Society of London, No. 210, 1881, p. 410; also Trans. of the Seismological Society of Japan, Vol. II, p. 45. It appears that the earliest attempt to apply the horizontal pendulum to the measurement of earthquake motions was made by Prof. W. S. Chaplin, of the University of Tokio, about 1878. His apparatus consisted of a wooden rod, free to turn about a vertical axis, and carrying at its end a rigidly attached block. It was intended that the motion of the earth should be recorded by a tracing point fixed to the block, writing on a smooth surface fixed to the earth below it. There was no multiplication of the motion, and either for this reason, or because friction was not sufficiently avoided at the joints and pointer, no results were ever obtained, and the apparatus was abandoned. The instrument described in the text was constructed in the summer of 1880 and recorded its first earthquake in November of the same year (see Transactions of the Asiatic Society of Japan, Vol. IX, p. 40). So far as the writer is aware, no continuous record of earthquake motion had been previously obtained by any observer. Some time before its exhibition to the Seismological Society the apparatus was shown to Messrs. J. Milne and T. Gray, who immediately adopted it (with the writer's consent), and have since employed it, with slight changes in details of construction, to measure artificial as well as natural earthquakes. Later, Mr. Gray communicated a paper to the Seismological Society "On Steady Points for Earthquake Measurements" (Trans., Vol. III, p. 1.), in which he described a number of other contrivances embodying the same dynamical principles (see below, §§ 27, 29 and 31).

(see § 24) the plate is kept revolving continuously in the direction of the arrow about a vertical axis fixed to the earth, and so long as no earthquake occurs each pointer traces over and over again the same circle on the revolving surface. During a disturbance each records the component transverse to itself of all the successive horizontal motions which may occur. The base-plate of each lever, which must of course be rigidly fixed to the earth, is clamped by means of three levelling-screws and a holding-down bolt in the centre to the top of a wooden post, firmly driven into the ground and cut off a few inches above the surface. Three convergent Vs, or a pyramidal hole, a V-slot and a plane surface are cut on the top of the post for the levelling-screws to press into. Either arrangement gives what Thomson and Tait* call a geometrical clamp, and, while affording perfect definiteness of support without any nice fitting, allows the apparatus to be removed and replaced in precisely the same position whenever that may be desired.

To reduce as far as possible the friction of the marking point on the glass plate, a light spring *h* is added (adjustable by the screw *i*), which carries a portion of the straw pointer's weight by means of the silk fibre *j*.

§ 24. *Improved form of Horizontal Pendulum Seismograph.*

Experience gained with the instrument described above led to a considerable modification of details, chiefly with the view of diminishing friction, and of rendering the apparatus less liable to get out of adjustment. The resulting form is shown in Plates II and III. In Plate II, fig. 4 is a general plan of the seismograph and driving clock complete; fig. 5 an elevation of the glass plate and sectional elevation of one of the pair of pendulums; fig. 6 an elevation of the driving clock, showing the speed-governor in section. In Plate III, fig. 7 is an isometrical drawing of one of the pendulums, and fig. 8 shows the method by which the glass plate receives motion from the clock. As before, each pendulum consists of a frame pivotted, about a vertical axis, to a fixed stand, and furnished with a massive bob which is pivotted to the frame about a line which is the instantaneous axis corresponding to the axis of support. A light prolongation of the frame forms the multiplying lever, whose motions are recorded on a continuously moving smoked-glass plate.

Each frame *a* (figs. 5 and 7) is a light triangle of steel, and the bobs are truncated cones of cast iron, pivotted to the frames in a manner which the figures sufficiently explain. The axis of support of each frame is defined by the points of two hard steel screws *b* and *c*, of which the upper one *b* works in a V-slot in a piece of agate, strongly supported by two wooden uprights fixed to the base-plate. One of the wooden uprights is removed in figs. 5 and 7 to allow the frame and other parts to be seen. The lower pivot *c* works in a conical socket of hard steel and points in the direction of the thrust (an improvement suggested to the writer by Mr. T. Gray)—that is to say its axis, if produced upwards, would

* Natural Philosophy, Vol. I, § 198.

pass through the point of intersection of a horizontal line through *b* and a vertical line through the centre of gravity of the whole suspended mass. The screw *c* is fixed to the steel frame once for all, but the upper screw *b* is adjustable and is provided with a jam-nut, in order that the axis of support may be brought into parallelism with the axis of the bob. The V-slot and conical holes into which the various points press are cut with a more obtuse angle than the points which enter them. The pointer is a light reed furnished at its writing end with a steel point, consisting of a piece of bent watch-spring filed sharp and glass-hardened. Its length is such as to give a record which is four times the actual displacement of the ground. The pointer is jointed to the steel frame at *d* (fig. 7) and the greater part of its weight is borne by a spiral spring of fine wire, hanging from a bent arm fastened to the frame by a pinching-screw at *e*, which allows the tension of the spring to be adjusted by raising or lowering the end of the arm. The spring supports the pointer near the joint and somewhat below the central line, an arrangement which permits the pressure of the marking end on the glass plate to be kept sensibly constant throughout a considerable range of up-and-down movement of the plate.

The glass plate is carried by a vertical steel spindle pivotted in a wooden stand between an agate cup at the bottom and a steel screw at the top, as is shown in figure 5. To enable the plate to be readily removed and a fresh one put in, it is attached to the spindle thus:—a circular brass plate *f* is permanently fixed to the spindle, and carries three inverted levelling-screws on whose points (which are covered with chamois-skin) the glass plate *g* rests. Next comes a soft leather washer and above it a stout brass washer *h*, which is pressed down on the plate by a wedged-shaped key *i* fitting in a slot in the spindle. The levelling-screws in *f* allow the plane of the plate to be easily adjusted: a rough adjustment is enough, since the jointed pointers are able to follow any up-and-down movements which the surface of the plate may make as it revolves.

The driving clock is an ordinary train of wheels driven by a weight of ten kilos., which is wound up once a day and has fall of about five metres. The speed is regulated by a governor whose construction will be clear from fig. 6. It consists of a vertical spindle carrying a pair of jointed rods, each provided with a pair of brass balls, and each carrying a fan which dips into a trough of oil when the governor revolves. The centrifugal tendency of the balls is partially resisted by a pair of springs which tie them to the spindle. The governor receives its motion by rolling contact between a disc fixed on the vertical spindle and another disc on the last axle of the clock-train. The clock drives the glass plate by a roller *k*, whose axle is made flexible at one point (*l*) in order that it may adapt itself to the varying height of the surface. This is done by cutting the axle at *l* and connecting the ends by a single turn of steel wire, which forms a convenient substitute for a Hooke's joint. The axle of the roller passes through a guide *m* (fig. 8), and close to the slot in which it works is a second shorter slot *n*. By lifting the axle into this, *k* is raised out of contact with the plate, whose motion

is accordingly arrested although the clock continues to run. One turn of the plate takes from a minute to a minute and a half.

In the figures the whole apparatus (except the clock, which is separately supported) is represented as mounted on a wooden patform on the top of a post stuck in the earth. Recently it has been found better to use a low solid stone table, as the warping of a wooden support is apt to produce a radial creeping of the pointers on the plate, and consequently a gradual widening of the lines they trace as the plate revolves.

In practice the horizontal pendulums have their axes of support slightly inclined forwards, to give a small degree of stability. This, indeed, must be given in all seismometers, partly to prevent the equilibrium from becoming unstable through any slight accidental change of adjustment, and partly to prevent any excessive displacement of the so-called steady point by the accumulated effects of frictional and other disturbing forces during a prolonged shaking.

§ 25. *Horizontal Pendulum Seismograph with Ring Bob.*

Another form of horizontal pendulum seismometer, representing a stage in the development of the instrument intermediate between the two forms already described, is shown in Plate IV, where figs. 9 and 10 give a sectional elevation and plan respectively. The construction will be evident from the drawing without explanation. There are, as before, two similar levers set at right angles to each other, which write their records on the same revolving smoked-glass plate, a portion only of which appears in the drawing. The distinguishing peculiarity of this form is the shape of the bob, which is a hollow cylinder wide enough to enclose the upright piece which affords a vertical axis of support. By this arrangement the two axes may be brought near together without necessitating the use of a small bob. The ring form has also the advantage of having a relatively great moment of inertia about its own axis, which gives it much power to resist the tendency of friction at its joints to set it in rotation during a displacement of the ground. This merit, however, does not counterbalance other practical defects and inconveniences in this modification of the instrument, which is on the whole decidedly inferior to the later form described in the preceding paragraph. The multiplying ratio of the instrument figured in Plate IV is seven to one.

§ 26. *Relation of the Friction Error to the dimensions of the frame and to the suspended mass.*

It is interesting to enquire briefly how the frictional error is likely to be affected by changes in the arrangement of the parts. For this purpose we may conveniently separate the whole frictional resistance into three parts—(α) that due to the marking pointer, (β) that due to the vertical component of the statical pressure on the pivots, (γ) that due to the horizontal pressures on the pivots, which

are exerted to balance the statical moment of the overhanging masses. The acceleration of the axis of support during an earthquake is usually so small that in considering the influence of friction at the pivots we may without sensible error restrict ourselves to the statical forces.

It is clear that the pressure on the pivots due to the moment of the overhanging weight will be reduced (other things being unchanged) by increasing the height of the upper pivot; this is one of the particulars in which the instrument of § 24 is better than those of § 23 and § 25. On the other hand, this pressure will be increased by lengthening the frame, in simple proportion to the length. But the vertical pressure on the pivots will not thereby be changed, and the moment of inertia of the system about the axis of support will be increased in duplicate proportion to the increase of length; hence if the relation of frictional couple to pressure on the pivots be constant, a considerable increase of steadiness would be given by lengthening the frame horizontally.

Again, if without changing the length or height of the frame we vary the distribution of mass between it and the bob (M_f and M_b, to return to the notation of § 18), it is clear that the vertical pressure at the axis of support, giving rise to (β), will be simply proportional to $M_f + M_b$, while the horizontal pressure giving rise to (γ) will vary as $r M_f + r' M_b$. The effective inertia is, as we saw in § 19, to be measured by $\frac{r}{r'} M_f + M_b$. It appears therefore that so far as it depends on horizontal forces at the pivots, (γ), the frictional error is not altered by any change in the distribution of the mass between the bob and the frame, but that as regards (β) the most favourable distribution will be to put as nearly as possible all the mass into the bob. In other words, the distribution actually made in the three instruments already described is the best not only as regards economy of material, but (what is of much more importance) as regards reduction of the frictional error.

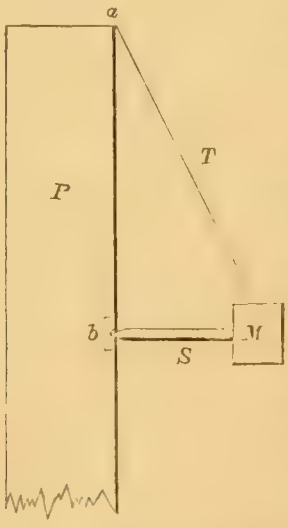
Next, if we suppose the ratio of the masses and the dimensions r, r' and the height of the frame to be unchanged, it is a question of much practical importance how great an amount of matter may advantageously be suspended. If the sliding surfaces of the pivots were quite rigid, and the coefficients of friction unaffected by changes of pressure, any increase of mass would produce a proportional increase of friction at the pivots, leaving however the part of the whole friction designated above by (α) unaffected. The whole friction would therefore increase less rapidly than the effective inertia, and consequently any addition of mass would be an advantage as regards steadiness.

But when additional weight is applied the pivots are compressed and therefore the amount of their sliding motion, relative to a given angular movement of the frame, is increased. Hence the resisting couple due to friction at the pivots increases in a much more rapid ratio than the effective inertia, when the weight is increased, and thus, although any addition to the weight gives an advantage in opposing (α), it introduces a disadvantage by giving more than

a proportional increase of (β) and (γ). Hence in any given case (other things remaining unchanged) there will be a certain value of the suspended weight which will give a *maximum* of steadiness. To attempt to calculate this maximum theoretically is out of the question, and no more than a very rough experimental determination is practicable. The desirable amount of weight will be small if (α) is a small part of the whole resistance. The writer's experience points to the conclusion that in practice the greatest steadiness is to be got by using a mass of no more than 1 to 2 kilos. as the bob of a horizontal pendulum seismograph. A mass greatly heavier than this, while it has more power to move its tracing index, tends so considerably to crush the hard steel points by which the supporting frame is pivotted, that the frictional error introduced by the pivots more than counterbalances the advantage gained.

§ 27. *Horizontal Pendulum with flexible tie and pivotted strut.*

Instead of using a rigid frame to carry the massive bob, we may suspend it by a single tie and strut, and by making the tie flexible we may avoid having a joint at its place of connection to the fixed support. Thus, in the sketch, M is



the heavy mass hung from a fixed post P by a wire T which ties it to the post at a, and held out so as to form a horizontal pendulum by the rigid strut S pivotted in a conical socket b. The mass M may of course either be fixed to S, in which case the steady line is at the axis of instantaneous rotation of the system, or it may be pivotted at the axis of instantaneous rotation of S alone (the mass of T being negligible). A prolongation of S beyond M forms a convenient writing pointer. A pair of similar instruments serve to register the two components of the horizontal motion. The necessary freedom of rotation about the axis of support ab is afforded by combined twisting and bending of the tie at a, whose elasticity gives a small amount of stability to the system. If that is too inconsiderable for practice it may easily be increased by advancing the point a slightly in front of the vertical line through b. Except for imperfect elasticity, there is no frictional resistance at a. The strut need not of course be horizontal, but by placing it so we reduce the stress on it, and consequently the friction at its pivot, to a minimum.

This modification of the horizontal pendulum is due to Mr. T. Gray, who has suggested it in his paper "On Steady Points for Earthquake Measurements", communicated to the Seismological Society of Japan shortly after the instrument described in § 23 had been exhibited. Figs. 11 and 12, Plate VII, show an elevation and plan of the instrument as described by Mr. Gray in the Philosophi-

cal Magazine for September 1881. There each bob consists of two masses MM fixed to the ends of a cross bar b, which is suspended by a wire t from an adjustable projecting arm c clamped to the post P. One of the bars b is bent to make it to pass clear of the other. The struts $a\,a$ are short compared with the length of the tie, and consequently bear only a small fraction of the weight. The multiplying arms $l\,l$ are inclined to the directions of displacement and parallel to each other, so that their records may be traced side by side—an arrangement which allows the two components of the motion to be more readily compared and compounded.

§ 28. *Horizontal Pendulum without joints.*

The method of suspension just described leaves one joint at which there is rolling contact and consequently friction, namely the socket of the strut; but there is no reason why we should not use a flexible piece instead of a joint there as well as at the other end of the axis of support. To do this it is only necessary to fork the strut, let its end project beyond the axis of support, and tie it back to that axis by an elastic wire, or preferably by a thin ribbon of tempered steel, placed with its flat side vertical. A fixed vertical pin standing in the axis of support and capable of sliding freely in a horizontal slot in the strut, is added to prevent any bodily translation of the strut to one side or the other during an earthquake, so that the hanging mass may have no freedom to move otherwise than by rotating about a nearly vertical line joining the upper and lower points of attachment.

This idea has been practically carried out in the instrument shown in Plate V. Fig. 13 is an elevation showing one of the two pendulums, and Fig. 14 is a sectional plan. The post P, firmly stuck in the earth, carries two horizontal levers L_1 and L_2 set at right angles to each other, to record two rectangular components of horizontal motion. The bobs M_1 M_2 are fixed to the rods L_1 L_2 and tied to a pair of small vices at the top of the post by fine steel wires $T\,T$. Fig. 15 is a plan of the top of the post, and shows the arrangement of the vices, which are fixed in a manner which gives them two (horizontal) degrees of freedom of adjustment. At the back end of each rod L is a fork (shown on a larger scale in figs. 16, 17, and 18) which consists of two parallel cheeks of brass $a\,a$ terminating in a vice b which is clamped by the screw-bolt and nut c. A split upright pin p is fixed to the post, and a short thin flat band of very flexible steel is clamped between it and b, the end of L. This is kept in tension by the thrust exerted by L, and when the horizontal pendulum swings the spring bends at or close to a vertical line in the centre of the pin. A sector of the pin, facing towards a, is cut out to give the spring room to bend about the axis of the pin (see figs. 16 and 18). The split sides of the pin p are pressed together by the nut n and so caused to hold the spring clamped between them. In fig. 18 one of the cheeks a is removed and the pin p shown in vertical section: the flat spring appears there and is lettered s. Only the upper portion of the pin p is

screw-tapped: the lower part is a smooth cylinder, and the cheeks *a a* pass just clear of it on either side, their distance apart being adjustable within small limits by the screw-bolt and nut *d*. Hence no horizontal translation of *L* can occur, and the only freedom of motion possessed by the suspended rod and mass is freedom to revolve about a nearly vertical line joining the upper end of *T* with the axis of the pin *p*. A pair of long bamboo rods R_1 and R_2 serve to multiply the motion, and record their displacements side by side on a revolving smoked-glass plate *G* by means of the hinged pointers t_1 and t_2. These are short pieces of straw tipped with steel, and each is provided with a little balance-weight *w*, behind the hinge, which lightens the pressure of the pointer on the plate and so reduces the friction. To bring the records parallel, the rod R_2 is set at right angles to L_2, and a counterpoise *W* serves to bring the centre of gravity of the system back into the line of L_2. The earth's motion is multiplied seven times in the record. The smoked-glass plate is similar in its arrangement of support and driving gear to the one shown in Plate II, but is of considerably larger size in the present case.

§ 29. *Horizontal Pendulum with two degrees of freedom.*

In the horizontal pendulum seismometers hitherto described, each piece has been capable of showing motion in one azimuth only—motion, namely, perpendicular to the plane containing its axis of support and its steady line; and a pair of pieces has therefore been necessary to determine horizontal movements in general. Mr. Gray* has adapted the horizontal pendulum to the determination of motion in any azimuth by making the pivotted supporting frame in two pieces placed in planes at right angles to each other, and jointed together in a vertical axis. The arrangement will be clear by reference to Plate VI, figs. 19 and 20. There, as in Plate IV, the bob is a ring. The primary axis of support is *a a* fixed to the earth. The pivotted frame which supports the bob consists of two parts *A* and *B*, jointed to each other with freedom of relative rotation about an axis *b b*, which stands to *a a* in the relation of axis of instantaneous rotation for the frame *A*. The bob is pivotted to *c c*, which bears a like relation to *b b* for the frame *B*. Multiplication of the earth's motion is effected by an independent lever, arranged vertically. It passes through a universal joint fixed to the base plate and has a small counterpoise near its upper end, where it touches c below the axis of the bob. Obviously the bob is not disturbed by a small horizontal movement in any direction.

In the next chapter other devices will be described, which allow the horizontal part of earthquake movements to be registered by affording in some cases a steady *line* with respect to motion in one azimuth, in others a steady *point* with respect to motions in all azimuths. Of instruments giving a steady line none is more successful and generally practicable than the simple horizontal pendulum; but of those which give a steady point it is probable that many yet to be described are preferable to the horizontal pendulum with two degrees of freedom.

* "On Steady Points &c."—Trans. Seismological Soc. of Japan, Vol. III, p. 5. An essentially similar instrument is figured in the Philosophical Magazine for Sept. 1881.

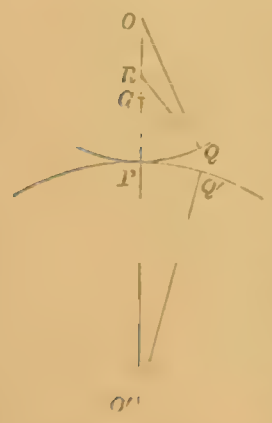
CHAPTER III.

OTHER INSTRUMENTS FOR OBSERVING HORIZONTAL MOVEMENT.

§ 30. *Mass free to roll.*

From what has been said in §§ 15 and 16 it will be obvious that any method by which a mass can be supported with one (or two) degrees of freedom to move horizontally, and in neutral or feebly stable equilibrium with respect to such movements, can be adopted in the design of a horizontal seismometer, the centre of percussion of the mass relative to its axis (or point) of support being taken as the standard of rest.

One method of support, in which the equilibrium can be made as feebly stable as may be desired, is given when a mass rests by means of a curved base on another plane or curved surface fixed below it, the mass having freedom to roll. The steadiness of the instantaneous axis may be increased by supporting a second mass there, with appropriate freedom of motion relatively to the first mass.



In the figure, let PQ be a portion of the base of the rolling mass, whose centre of gravity is at G, and PQ' a portion of the fixed surface on which the mass is free to roll. Let O and O' be the respective centres of curvature. In the initial position of equilibrium the line OO' is supposed to be vertical and therefore contains G. Now let the mass be displaced through a small arc PQ, and let PQ' be made equal to PQ. The displacement brings Q into contact with Q', and causes the radius QO to form a prolongation of the radius $O'Q'$. Hence a line QR, drawn so that the angle OQR is equal to $PO'Q'$, will be vertical in the new position. The equilibrium, with respect to the assumed displacement, will therefore be stable if G is below R, neutral G if coincides with R, and unstable if G is above R.

Writing r and r' for the radii of curvature OP and OP' respectively, and s for the arc through which the point of contact moves, we have in the triangle ORQ

$$OR : r = \sin \frac{s}{r'} : \sin \left(\frac{s}{r'} + \frac{s}{r} \right),$$

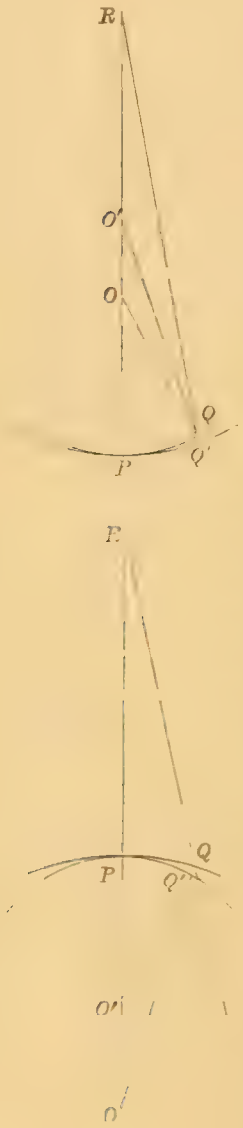
$$= r : r + r',$$

if we assume s to be exceedingly small compared with the radii.

Hence $$PR : r = r' : r + r',$$

and the condition which makes the equilibrium neutral in very small displacements is that

$$PG = \frac{r\,r'}{r + r'}.$$



If the surface of the support is concave, as in the adjoining figure, the condition giving neutral equilibrium is

$$PG = \frac{r\,r'}{r' - r};$$

while if the surface of the support is convex, and the base of the rolling mass concave, as in the lower figure, the condition becomes

$$PG = \frac{r\,r'}{r - r'}.$$

The seismometrical application of this method of getting neutral equilibrium appears to have been limited to the case of a spherical or cylindrical mass rolling on a plane surface. In that case the formula gives $PG = r$, a condition which is actually fulfilled by a homogeneous spherical ball or solid or hollow circular cylinder of uniform thickness; and the equilibrium is then neutral for large as well as for infinitesimal displacements, a fact which makes rolling spheres and cylinders suitable for the registry of large earthquakes. In some applications which have been made, the spherical or cylindrical mass has been used alone, its centre of percussion or instantaneous axis forming the steady point or steady line with respect to which measurements of the motion of the supporting table have been taken. In other cases the ball or cylinder has been used to support a second mass which furnishes the greater part of the effective inertia of the system.

§ 31. *Rolling Sphere Seismograph.*

The latter plan was adopted in what appears to have been the earliest seismometer of this class—an instrument designed and used to measure earthquakes in Japan by Dr. G. F. Verbeck in 1876-7. In Dr. Verbeck's apparatus the supporting table was a marble slab, with its upper surface ground plane and carefully levelled. On this four balls of rock-crystal were placed (three would have been sufficient) each about one inch in diameter, and on them was laid a

massive block of hard wood whose weight greatly exceeded that of the balls. In the centre of this a vertical tubular hole was bored, in which a weighted pencil, sliding freely, was carried, its point resting on a piece of paper fixed to the slab below. This gave a static record of the relative motion of the block and the slab, without multiplication.*

A similar instrument in which the base-plate is of glass, and the record is given by a steel needle writing on a smoked-glass plate, has recently been described by Mr. C. A. Stevenson to the Royal Scottish Society of Arts, and has been applied by him to the measurement of earthquakes in Scotland.

It appears to have been assumed by these observers that (except for friction) the block resting on the balls would remain at rest during a horizontal displacement of the base. A little consideration, however, will show that when the base-plate moves in any direction the block will in all cases move through a small distance in the opposite direction. The centre of percussion of a spherical ball taken separately is at a height of seven-fifths of the radius from the bottom, and hence if we wish to keep the block at rest it must be supported at that height instead of at the top of the balls. Placed where it is, it has the effect of raising the centre of percussion or steady point of the system considerably, but that necessarily remains below the top of the balls. We may conveniently examine the kinetic qualities of the system by considering the upper block as equivalent to a number of particles, one situated always at the top of each ball. When three balls are used the mass of each of these particles is to be taken as one-third the mass of the block. Calling the mass of the block 3M, that of each ball m, and the radius of each ball r, the system is kinetically equivalent to three pieces standing upright, the moment of inertia of each about the base being

$$\tfrac{7}{5}mr^2 + 4\mathrm{M}r^2,$$

and the height of the centre of gravity of each from the base is

$$\frac{mr + 2\mathrm{M}r}{m + \mathrm{M}}.$$

Hence the centre of percussion of each is at a height above the base equal to

$$\frac{\tfrac{7}{5}mr^2 + 4\mathrm{M}r^2}{mr + 2\mathrm{M}r} = \frac{r\,(\tfrac{7}{5}m + 4\mathrm{M})}{m + 2\mathrm{M}}.$$

This, which is $> \tfrac{7}{5}\,r$ and $< 2\,r$, is the height of what we may here call the *steady plane* of the system above the base, and this position should be taken as the standard of rest in reckoning the displacement of the earth's surface. When the base moves through a distance s, the top of each ball (and therefore the block) moves oppositely through a distance

$$s\left\{\frac{\tfrac{3}{5}m}{\tfrac{7}{5}m + 4\mathrm{M}}\right\}.$$

* Dr. Verbeck tells the writer that he designed, but never used, a lever arrangement by which a multiplied record of the earth's motion would have been given.

and, if there were no friction, the records given by a tracer fixed to the block should be reduced by this amount. In Dr. Verbeck's instrument the mass of the block was so great relatively to the mass of the balls that the impulse which their inertia gave to the block must have been negligible: in other words the steady plane must have been exceedingly close to the top of the balls. The effective inertia of the system (with three balls) is

$$\frac{3\,(m + 2\mathrm{M})^2}{\frac{7}{5}m + 4\mathrm{M}}.$$

§ 32. *Friction in the Rolling Sphere Seismometer.*

Friction, or rather rolling resistance, constitutes a serious source of error in the indications, and has of course the effect of making the recorded displacements smaller than they should be by an amount depending, in a given instrument, on the rate of acceleration of the earth's surface during the disturbance. According to Rankine (Applied Mechanics, § 682) the rolling resistance may be taken as a couple whose moment is found by multiplying the normal pressure between the rolling surfaces by an arm whose length (which we will write l) depends on the nature of the surfaces. To simplify matters we may consider separately these two cases: (1) mass and weight of balls negligible compared with block, as in Verbeck's apparatus; (2) no block, the inertia and pressure being due to a spherical ball alone.

In (1), calling the mass of the whole block M, the pressure at the top and also at the bottom of the balls is $\mathrm{M}g$ and the couple due to rolling resistance at these two places is $(l + l')\,\mathrm{M}g$, where l and l' apply to the two pairs of surfaces. This is equivalent to a horizontal force $\frac{(l + l')\,\mathrm{M}g}{2r}$ applied to the block, and produces an acceleration $\frac{(l + l')\,g}{2r}$.

In (2), calling m the mass of the ball, the effective inertia (or mass referred to the steady point) is $\frac{7}{5}m$, and the couple due to rolling resistance is lmg. This is equivalent to a force $\frac{lmg}{\frac{7}{5}r}$ applied at the steady point, and produces a horizontal acceleration there equal to $\frac{lg}{r}$. Hence it appears that both arrangements are affected by rolling friction to the same extent, provided we use balls of the same radius in both, and the same two materials at each place where rolling contact occurs.

Rankine gives the following values for the arm l expressed in feet:—

Oak on oak	0.006 (Coulomb)
Lignum-Vitæ on oak	0.004 „
Cast-iron on cast-iron	0.002 (Tredgold).

If we suppose that by choosing suitable substances for fixed slab, balls, and block, the value of l and l' can be reduced to, say, half of the least of these, or

0.001, we find (taking $r = \frac{1}{2}$ inch, as in Dr. Verbeek's apparatus) the acceleration of the block by rolling friction to be $-\frac{g}{42}$. In a later chapter it will be shown, as the result of direct observations, that the horizontal acceleration of a particle on the earth's surface does not reach this value except in earthquakes of considerable intensity, and even then falls short of it during a great part of each displacement. Hence, apart from the friction of the writing pointer, an instrument of this kind is likely to possess so much resistance that it will fail altogether to record small earthquakes, and give a very imperfect record of others which are great enough to leave some traces of their passage. A frictional acceleration amounting to one-fortieth of the value of gravity is altogether out of the question in a seismometer, and it appears that even by increasing greatly the radius of curvature, a rolling mass seismometer cannot easily, if at all, be brought to the state of efficiency which is reached without difficulty by the horizontal pendulum and other devices, and which is indispensable to accuracy in the measurement of small earthquakes.

§ 33. *Other Rolling Sphere Seismographs.*

A single solid spherical ball has been used by Mr. Gray and is figured in fig. 21, Plate VII. The following description of it is, with the figure, taken from the Philosophical Magazine for September, 1881 :—

"A sphere of lead,* iron, or any other heavy substance rests on a flat plate *B* made truly plane and furnished with three levelling screws *L*. An arm *A*, fixed to the base *B*, is so formed that a circular ring fixed to its end is held in a horizontal position with its centre vertically above the highest point of the sphere. This ring carries a species of spring universal joint, consisting of four very light bent springs, *j*, arranged at right angles to one another and meeting in a small round disc, *b*, at the centre. The lower end of the lever, *l*, passes through this ring *b*, and is fixed to it at such a point that its lower end, which is rounded, just fits a small hole in the top of the sphere *S*. Between *S* and *b* a small sphere, *s*, is fixed to the lever *l*, and is so proportioned that the lever *l*, when pushed at *b*, tends to rotate around a point a little above its lower end, thus diminishing the push on the sphere *S*. The springs *j* serve to allow the lever *l* to turn in any direction, and are made so light that they can only make the ball roll with a very long period. When thus proportioned they serve the purpose of a universal joint, and at the same time give a little stability to the parts, thus preventing the plate *P*, if it be put in motion, from causing the ball to roll over. The lever *l* is a rod of bamboo which is at the same time very light and rigid; at the upper end the rod is flattened and hinged just above the bend by a piece of tough Japanese paper glued to its upper side . . . . .

* Lead would be an exceedingly unsuitable material on account of its viscosity, which by allowing it to flatten out at the bottom, especially after a long time of rest, would give great resistance to rolling and an objectionable stability for small displacements. (J.A.E.)

The multiplication given by an instrument of the sort may be determined experimentally; or it may be approximately calculated by taking a point O at a height equal to seven-fifths of the radius of the large sphere S as nearly steady."

In other instruments used by the same observer a segment only of the rolling sphere has been employed, with an independent mass pivotted at the centre of percussion, which is arranged to be at such a height above the centre of the spherical segment that the equilibrium of the system is nearly neutral. "This method of construction allows the radius of the sphere to be much increased; but it introduces a difficulty of adjustment, a complication of parts, and generally a slight want of symmetry, which causes a little uncertainty in the interpretation of the records."* An instrument of this class is shown in fig. 22, Plate VII. There the point P should be the centre of percussion of the rolling segment S, to secure which the weight W can be moved up or down. By varying the mass of the pivotted ring R the centre of gravity of the system can be brought below the centre of curvature just enough to give a small amount of stability.

A simpler arrangement, and one yielding nearly as much effective inertia in proportion to the pressure on the base, is a solid mass with as condensed a form as possible, rigidly attached to a light spherical segment which rolls on a fixed plane base. The centre of gravity of the whole piece must be a very little below its centre of curvature (unless a small amount of stability be given by other means), and its centre of percussion, which lies only a little way above the centre of gravity, is of course to be taken as the steady point. In the instrument described above the pivotted ring is equivalent to a particle of the same mass situated at P: the arrangement now mentioned, which is much easier of construction and adjustment, approximates closely to the former in proportion as the dimensions of the bob (here fixed, instead of being pivotted) are reduced, without reduction of its mass.

§ 34. *Rolling Cylinder Seismograph.*

The seismometers of §§ 29-31 are intended to record horizontal motion in any direction. To restrict the record to one azimuth it is only necessary to use a rolling surface without curvature, and therefore without freedom to roll, in a line perpendicular to the direction of the motions which are to be registered. Thus a pair of circular cylinders placed at right angles to each other on a plane base may be used to give separately two rectangular components of earthquake motion perpendicular to their respective axes.

This plan has been adopted by Mr. Gray in an instrument described before the Seismological Society of Japan (Trans., Vol. III, p. 143) and again in the Phil. Mag. for September 1881. Fig. 23, Plate VII, shows the construction. The cylinders are marked c and c'. A bent arm A, which is fixed to the base-plate and passes over one cylinder, supplies fulcrums for a pair of multiplying pointers ll'. The cylinders are made hollow, and hence the steady line of each

* Gray, *loc. cit.*

comes near the top. Calling r_1 the external, and r_2 the internal radius, the height of the steady line above the base is

$$\frac{3\,r_1^2 + r_2^2}{2\,r_1}.$$

To give a small degree of stability, Mr. Gray suggests the use of a small cylinder rolling freely inside each of the larger ones. A spring, or a light pendulum hung from above and gearing with the axis of the cylinder, might be used. "An interesting modification of this machine might be made by placing two equal cylinders on a horizontal plate with their axes parallel, and placing on them a second horizontal plate so that its upper surface should always be in a plane through their instantaneous axes. This could be done by causing the plate to rest by means of arms on two pairs of smaller cylinders of proper dimensions, so disposed that each of the larger cylinders should bear at each end one of the smaller cylinders coaxial with the larger cylinder and projecting from it. A third cylinder placed on the upper plate with its axis at right angles to those of the first two would, for small motions of the earth, have a line in itself which would remain approximately at rest." It must, however, be admitted that this elaborate plan for a seismometer with two degrees of horizontal freedom has little to recommend it.

For large motions Mr. Gray proposes to arrange the multiplying levers so that when the displacement exceeds a given value they will go out of action, and a direct writing appliance take their place. "A very simple method of writing large motions would be to attach a fine point to the end of the cylinder at its centre, and allow this point to write on a plate placed in front of it and fixed to the base-plate." This would give a record equal to rather more than half the actual motion.

Compared with the rolling sphere, the rolling cylinder seismograph has the advantage of easier construction; to turn a cylinder accurately being a matter of far less difficulty than to turn a sphere. It is however, equally with the rolling sphere, liable to the great practical objection that its frictional resistance is so great as to prevent it from properly recording a slowly changing motion of the ground.

§ 35. *The Common Pendulum.*

It has been already pointed out that a mass hanging pivotted by one point to a fixed support, so that its centre of gravity lies vertically below its point of support, fails to act as an absolute seismometer on account of the stability of its equilibrium. The arrangement forms, of course, a common pendulum, and is liable to the objection that during any prolonged shaking of the support the pendulum acquires a swing whose amplitude may be, and often is, greater than the motions of the ground.

If, however, we make the length of the pendulum very great, its equilibrium will be as nearly neutral as, in fact, it is ever desirable that the equilibrium of a

seismometer should be. If its period of swinging is much greater than the periods the earthquake waves, these will not generally communicate any immoderate motion to it, and even if it swings considerably there will no difficulty, provided the motions are recorded on a continuously moving plate or drum, in distinguishing the long-period waves due to the swing of the pendulum from the relatively much shorter waves due to the motion of the ground. The latter are superposed on the former, and in measuring them the undulating path traced out on account of the swing is to be taken as the datum line, or line of no displacement, instead of the line which would be traced if the pendulum had remained rigorously at rest.

The tendency of a pendulum to acquire a swing when its point of support is shaken may be reduced and even completely obviated by introducing frictional resistance, which dissipates, more or less completely, the energy communicated to the hanging mass by the successive horizontal impulses to which it is subjected. This action necessarily occurs to a certain extent in all seismographs, a certain amount of friction being inevitable, especially where the earth's motion is considerably multiplied by a recording lever. The friction may of course be purposely increased, and by doing this even a short pendulum may be prevented from acquiring a swing during a prolonged disturbance. But any introduction of friction involves a sacrifice of accuracy in a seismometer, and the effect of adding enough resistance to prevent a short pendulum from swinging is that it altogether fails to record minute earthquakes, and gives unduly small indications during more considerable shocks.

Many observers have used for the measurement of earthquake motion a pendulum provided with a tracing point or other kind of index by which its greatest displacement from the vertical is registered. Now it is clear that if the pendulum is liable to be set swinging during an earthquake such indications are wholly without value. They depend not only on the amplitude but also on the duration of the disturbance, and, very directly, on the period of the waves. They may be, and often will be, many times greater than the motion of the ground.

On the other hand, if the pendulum is so much retarded by friction that the energy which it receives by any one displacement of the point of support is dissipated before the next displacement occurs, no accumulation of small motions can occur. The pendulum will not swing, and its greatest displacement cannot exceed, but will actually be always less than the greatest motion of the ground during the disturbance.

If we attempt to obtain, by means of a pendulum, a *static* record of earthquake motion—that is a record inscribed on a stationary plate (or registered by some other equivalent contrivance) instead of on a continuously moving plate—then, since we have no means of distinguishing (in the record) earthquake motions proper from the swing of the pendulum, we must resort to the arrangement just mentioned. That is to say, the pendulum must have enough frictional

resistance to prevent it from acquiring a swing. If, however, we allow the motions to be traced on a continuously moving record-receiver, any moderate swinging of the pendulum, provided that is of much longer period than the earthquake waves, is not seriously objectionable, and we may then reduce the friction as far as possible. The same remarks apply with equal force to all forms of seismometer in which a so-called steady point is sought after. In all such instruments, static records have no meaning or value unless swinging is entirely prevented. This can be done by introducing enough friction, but to do it, especially when the stability of the free mass is considerable, involves a great sacrifice of accuracy —a sacrifice which there is no need to make when a continously moving record-receiver is used.

§ 36. *Actual Pendulum Seismometers.*

Mr. R. Mallet, writing in 1858, refers to the common pendulum, as "the oldest, probably, of seismometers, long set up in Italy and southern Europe. A pendulum, free to move in any direction, carries below the bob a style partly immersed in a stratum of fine dry sand, spread to a uniform thickness over the concave surface of a circular dish placed beneath, marked to the cardinal points, whose centre is beneath the point of suspension of the pendulum when at rest, and whose concavity is that of a spherical segment of a radius equal to the length of the pendulum and style, plus rather more than the depth of the stratum of sand. It was supposed that the style would mark a right line when seen in a plane vertical to the sand-bed, and in the direction of the shock."*

Pendulums provided with sliding pencils writing on paper fixed below, or with some other contrivance for giving static records, have also been used at Comrie, in Scotland†, by a committee of the British Association; in Japan, by Dr. Verbeck (in 1871) and subsequently by Wagener, Knipping, Milne, Gray, and others; at Rome by Secchi; at Manila by Faura‡; and no doubt by many observers in other places. In one of Mr. Milne's arrangements a long pendulum, hung from the roof of a house, carried two vertical sliding styles which rested on the surface of two strips of smoked glass on a table below. The strips of glass were started into motion by an earthquake disturbance (which released a catch) and passed under the styles, moving in lines at right angles to each other. This gave a continuous record of the motion of the pendulum, without multiplication, beginning at an uncertain interval after the beginning of the earthquake, and lasting for only a few seconds.** Dr. Wagener's apparatus (successfully used by Mr. Knipping in Tokio from 1878) was a pendulum 3 feet long supported by a rigid frame, and provided with a multiplying lever by which the relative displacement of the earth and the bob of the pendulum was magnified 24 times.

* British Assoc. Report, 1858, p. 73.
† British Assoc. Report, 1841, p. 46.
‡ Proc. Royal Society, Vol. XXXI, p. 460.
** Trans. of the Seismological Society of Japan, Vol. III, p. 12.

The lever was pivotted to a fixed support by a ball and socket joint, and connected to the pendulum by a ball and tube joint. The motions of its long end were registered by its pulling up a thread through a hole in a plate fixed immediately below it. The thread was wound round a light pulley to which an indicating pointer was attached. Another pendulum instrument was arranged with eight indices, and was designed to give the direction of the horizontal displacement. Dr. Wagener's scheme also included a continuously registering seismograph, in which the motions of a pendulum were to be recorded on a drum, started into rotation by the earthquake, and travelling longitudinally as it revolved, by means of a screw on its axis. This part of the plan does not appear to be been put in practice.*

§ 37. *Long Pendulum Seismograph.*

A long pendulum seismograph provided with a pair of multiplying levers by which two components of the horizontal motion were recorded on plates kept in continuous motion by a clock, was designed and erected by the present writer in 1879. Of this instrument, which was probably the earliest continuously recording seismograph to be actually constructed and successfully used, a description will be found in Vol. I of the Transactions of the Seismological Society of Japan. Separate smoked-glass plates were used to receive the traces of the two pointers. This introduced certain practical difficulties, and the original arrangement was also objectionable on account of the smallness of the plates. A modified form has since been adopted, and is now in use in the writer's observatory. The instrument as it now stands is shown in Plate VIII.

Fig. 24 gives a general view of the structure by which the point of suspension of the pendulum is supported. It consists of a very rigid wooden framework, firmly founded on piles, and rising above the ground to a height of over six metres. This is completely detached from the walls and roof of the building in which it stands. The pendulum consists of a massive ring of cast-iron *a*, weighing 25 kilogrammes, and hung in a horizontal plane from the top of the framework, by three wires *b b b*. A screw and nut at the top allow the height of the ring above the ground to be adjusted. To record the motion of the earth relatively to the "steady point" of the pendulum (which is, of course, its centre of percussion) two appliances are provided, which may be used either alternatively or both together. In one of these the complete horizontal motion is recorded by a single pointer: in the other, two rectangular components of the horizontal motion are recorded by separate pointers, but on the same plate. The first arrangement only is shown in fig. 24, and is also shown, on a larger scale, in figs. 25 and 26. The second arrangement is shown in figs. 27 and 28.

The ring-bob of the pendulum (shown in section in figs. 25 and 27, and in plan in figs. 26 and 28) carries an iron bar *c* across one of its diameters, in the

* Trans. of the Seismological Society of Japan, Vol. I, p. 54 and Vol. III, p. 107; also Mittheilungen der deutschen Gesellschaft für Natur- und Völkerkunde Ostasien's, 1878 and 1879.

centre of which a brass tube *d* (fig. 25) is fixed. The upper end of the multiplying lever is a brass ball fitting easily but not loosely into this tube; it stands at such a height in the tube as to be at the centre of percussion of the pendulum. The fulcrum of the multiplying lever is a gimbal joint (see fig. 26) giving freedom of rotation in any azimuth, but no freedom to rotate about a vertical axis. This is carried by a stiff iron bar *e* projecting from a wooden upright *f*, which is firmly nailed to a post *g* (fig. 24) stuck fast in the ground. The projecting bar *e* is slotted where it is fixed to *f* by a screw-bolt, so that the position of the gimbal joint may be adjusted horizontally, by turning *e* round or pushing it out and in. Below the fulcrum the multiplying lever consists of a light bamboo rod *h*, terminated by a fork in which the marking index *i* is jointed on a horizontal axis. The pointer is a piece of straw tipped with steel: it rests on the smoked-glass plate *j*, and its pressure is adjustable by a small counterpoise *k*. The glass plate is supported in the manner already shown in Plate II, and stands on a board fixed to the top of the post *g*. It receives continuous motion from a clock, by means of a roller, in precisely the same manner as the glass plate in Plate II. The plate is kept continuously revolving, in expectation of an earthquake, and it is found that although the whole apparatus is remarkably free from friction, the line traced on the plate does not widen to any very objectionable extent, in the absence of earthquakes. The multiplying ratio is ten to one.

The additional, or alternative, arrangement shown in figs. 27 and 28, allows the same pendulum to serve as a two-component machine. A brass plate *l* is fixed to the cross-bar *c* at the level of the centre of percussion of the pendulum. In this two slots are cut, at right angles to each other (see fig. 28, where a portion of the bar *c* is removed), and in these slots the bent-up ends of two short horizontal levers *m*, *n*, slide. *m* and *n* are pivotted about vertical axes at *o* and *p*. The supports of these axes are fixed to the earth. Beyond the axes *o* and *p*, to the right, are two light continuations of the levers *m* and *n*, arranged parallel to each other. These (*q* and *r*) record their motions on a large revolving smoked-glass plate, a portion of which is shown at *s*. It will be obvious that a horizontal motion of the earth parallel to *n* will simply cause *n* to slide in the plate *l* without affecting the pointer *r*, but will cause *m* to revolve about the axis *o*, and will therefore be recorded on a magnified scale by the pointer *q*. One of the two levers *m n* is bent so as to pass below the other without touching it. The upright ends by which they receive the motions of the bob are cylinders, working easily, but without shaking, in the slots in the plate *l*. The long pointers *r* and *q* are jointed horizontally near *o* and *p*, (see *q*, fig. 28) so that they may follow inequalities of level in the revolving glass plate.

The inertia of the bob *c* is so great that there is no objection, on the score of friction, to the simultaneous use of both arrangements for recording, and they are constructed so as not to interfere with each other. The recording levers are so light that their influence, both static and kinetic, on the bob is negligible.

§ 38. *Influence of friction on the Pendulum and other Seismometers.*

Before going further, it may be useful to enquire more particularly into the effect of frictional resistance on a pendulum seismometer, in order that we may estimate the amount of inaccuracy which is introduced when enough friction is added to make static records practicable, by preventing the pendulum from swinging. The theory is in fact applicable not only to the common pendulum, but to all seismometers whose stability would (in the absence of friction) cause them to execute simple harmonic oscillations.

Let M be the effective inertia of the instrument—in other words the mass referred to the steady point. Let F be the force per unit of that mass (due to stability, and leaving friction out of account) which tends to restore the mass to its position of equilibrium when the steady point is displaced through unit distance from that position. Then, by the assumed condition, the total restoring force when the displacement is r is equal to $r\,M\,F$. Also, let f be the frictional resistance referred to the same point. This, which is made up of forces at the point or axis of suspension, at the fulcrum of the multiplying pointer, at the joint by which the pointer is connected to the main mass, and at the marking pointer, will, in general, be a constant force, sensibly independent of the velocity. Let the mass be displaced so that the displacement of the steady point from its position of equilibrium is r_0. It will swing back, and over to the other side to a distance of, say, r_1 from the position of equilibrium. During this motion the energy dissipated through friction is $f(r_0 + r_1)$. This must be equal to the loss of potential energy which is

$$\int_{r_1}^{r_0} r M F\, dr, \quad \text{or} \quad \frac{M F (r_0^2 - r_1^2)}{2}.$$

Hence

$$r_0 - r_1 = \frac{2f}{MF},$$

and the same expression will give the decrease in amplitude of displacement during every succeeding half-swing. The amplitudes diminish in arithmetical progression, successive displacements to the same side differing by $\frac{4f}{MF}$.

From the above equation

$$f = \frac{(r_0 - r_1) F M}{2},$$

we have $\frac{(r_0 - r_1) F}{2}$ for the acceleration which the frictional resistance produces whenever it acts. F, if not directly calculable, is easily determined by observing the period of free oscillation of the suspended mass,* and $r_0 - r_1$ may be at once determined by experiment in any actual instrument.

An earthquake in which the acceleration of the ground did not exceed this quantity, $\frac{(r_0 - r_1) F}{2}$, would occur without affecting the instrument, and would

* Since the complete period of free oscillation is $\frac{2\pi}{\sqrt{F}}$.

altogether fail to be recorded. The record of a sharper shock, given on a moving plate, would be diminished by friction to an extent not easily calculable, even if we assume a definite character (e. g. simple harmonic oscillation) for the motion of the ground; and the actual motions which occur during an earthquake are of too irregular a character to make any such assumption even approximately correct.

Taking now the case of a common pendulum, let l be the length of the equivalent simple pendulum, or in other words the distance of the steady point from the point of suspension. Then for any *small* displacement r, the restoring force (neglecting friction) is $\frac{r\,Mg}{l}$, and the decrease of amplitude in a semi-oscillation

$$r_0 - r_1 = \frac{2fl}{Mg}.$$

Hence the acceleration due to friction, when it acts, is $\frac{(r_0 - r_1)\,g}{2l}$.

Observations with the long pendulum described in § 37 have shown that $r_0 - r_1$ is 0.03 cm. in the ordinary condition of the instrument. Hence, since the length l is 540 cm., the acceleration due to friction is $\frac{0.03\,g}{2 \times 540} = \frac{g}{36000}$ or 0.027 cm. per sec. per sec. It is certain that a frictional resistance so small as this has no considerable influence on the records of even very minute earthquakes.

§ 39. *Short Pendulum with considerable friction.*

Mr. Gray (Phil. Mag., Sept. 1881, p. 203) has advised the use, for earthquake measurement, of a short (3 feet) pendulum provided, purposely, with enough frictional resistance to bring it to rest after one half-swing when the initial displacement is about that of the largest earthquake likely to occur, the object being of course to avoid swinging. To fit such an instrument for use in Japan we should provide for a maximum displacement of about 1 cm., and, to prevent swinging, r_1 must be zero when the pendulum swings back after this extent of displacement. Taking the length as 1 metre we should then have the acceleration due to friction $= \frac{g}{200}$, or 4.9 cm. per sec. per sec. This is a value much in excess of even the *maximum* acceleration which occurs during many minor earthquakes, and these would therefore fail to be recorded. Probably even so considerable an amount of friction as this would not introduce any very large error into records of the greatest movements which the apparatus was fitted to record, but it would certainly prevent many earthquakes from being recorded at all; it would give a much reduced record of greater motions; and it would curtail such records as it gave, by causing the pendulum to end its registrations long before the motion of the ground ceased—since the later part of an earthquake

consists always of slowly dying out undulations whose period is considerable and whose amplitude is small. The same objections would apply, with scarcely diminished force, to an instrument in which the frictional resistance was even two or three times less than the value given above.

§ 40. *Methods of making a short pendulum astatic.*

Various plans have been proposed for reducing the stability of a short pendulum sufficiently to fit it for seismometric work. Mr. Gray* has suggested to fix on the bob a circular trough containing some liquid, which, when the pendulum is deflected, will accumulate on the inner side so as to bring the centre of gravity of the system back to (or nearly to) the vertical line through the point of suspension. Another plan is to use a ball rolling in a hollow curved surface fixed to the bob, such as a sphere whose radius is longer than the pendulum. "Another method would be to attach a vertical spiral spring to a point in the axis of the pendulum a little below the point of suspension and to a fixed point above it, so that when the pendulum is deflected it would introduce a couple."

The present writer† has suggested the following arrangement:—Let the bob of the pendulum be jointed to the top of a short vertical lever which is pivotted below the bob by a gimbal, or ball and socket joint, to a fixed support, and let the connection of the lever with the bob be a ball and tube joint, so that the top of the lever may be free to accompany the pendulum in all its (small) displacements. Let a point on this lever anywhere between its pivot and the bob of the pendulum be connected by a stretched spiral spring to a point (fixed to the ground) vertically below and at some distance from the pivot of the lever. Then when the pendulum is deflected to any side this spring will exert, through the lever, a force tending to increase the deflection; and by a proper arrangement of parts this force may be made very nearly sufficient to hold the pendulum deflected against gravity, and so to give a condition of nearly neutral (feebly stable) equilibrium throughout a range of motion equal to that of the largest earthquakes the apparatus is intended to record.

§ 41. *Duplex Pendulum Seismometer.*

An instrument resembling these in its action, though materially different in its design, has been invented and successfully applied to the measurement of earthquake motion, by the present writer, under the title of the Duplex Pendulum. It consists of a combination of a common with an inverted pendulum. The common pendulum is stable: the inverted pendulum with a rigid pivotted supporting rod is unstable: by placing an inverted pendulum below a common one and connecting the bobs so that any horizontal displacement must be common to both, we may make the equilibrium of the jointed system neutral or as feebly stable as may be desired. The following description is taken, with little alteration,

* Transactions of the Seismological Society of Japan, Vol. III, p. 145.
† Ibid., p. 147.

from the writer's original account of the instrument, given in the Transactions of the Seismological Society of Japan, Vol. V, p. 89. The reference letters apply to Plate IX, figs. 29 and 30, of the present memoir, which give two sectional elevations of the instrument, taken at right angles to each other.

B_1 is the bob of the upper or common pendulum, consisting of a hollow cylinder of lead hung (with freedom to oscillate in any azimuth) by two light wooden rods *a a* from a cross piece *b*, which carries a steel pin *c* whose point rests in a conical cup of agate let into the upper fixed support S_1. S_1 is a rigid bracket standing out from the top of a post fixed in the earth. B_2, also cylindrical, is the bob of the lower or inverted pendulum. It is fixed to a stout circular rod *d* which is pivotted to a second fixed support or base S_2 by a somewhat peculiar joint. Two feet *ee* fixed to the rod of the inverted pendulum stand respectively in a conical hole and a V-slot on the upper surface of a steel plate *f*, on the lower surface of which there are another conical hole and V-slot in a line at right angles to the line of those on the upper surface. Into the lower hole and V a pair of inverted feet fixed to S_2 press up. The upper and lower slots and holes are arranged so that their vertices are all in the same horizontal plane. This mode of support also gives freedom to oscillate in any azimuth, and it is employed instead of the more simple method of pivotting a single foot in a single conical hole, in order that there may be no freedom on the part of the lower pendulum to rotate about a vertical axis. There is therefore no objection to using a prolongation of the lower pendulum as the indicating pointer. The bobs B_1 and B_2 are connected thus:—from a rigid brass bar extending across the top of B_1 there depends a rigid vertical projecting piece ending with a spherical ball which just fits in a cylindrical hole in a tube fixed to B_2. The pendulums therefore move freely together, this joint giving them the necessary power of vertical sliding relatively to each other through a small distance.

The spherical ball on B_1 and the tube on B_2 are placed so that their point of contact is at the centre of percussion of both pendulums. This is the *kinetic* condition which must be fulfilled in order that this point should be the "steady point" when a displacement of the earth occurs. The point of contact is, of course, a short distance below the centre of gravity of B_1 and above that of B_2.

If for brevity we call W_1 and W_2 the weights of the pendulums referred to this point (that is, the actual weight of each multiplied by the distance of its centre of support from its centre of gravity and divided by the distance of its centre of support from the point of contact between the ball and tube, then the *static* condition which will give neutral equilibrium in very small displacements is that

$$W_1 l_2 = W_2 l_1,$$

where l_1 and l_2 are the lengths of the pendulums measured from their point of contact to their respective points of support. In practice a small margin of stability must be given by making $W_1 l_2$ somewhat greater than $W_2 l_1$.

The multiplying lever consists of a light wooden rod g rigidly fixed to B_2 by a bridge h, and therefore forming a prolongation of d. At the top of this a light arm of straw i is jointed (with freedom of motion about a horizontal axis), and stands out horizontally with its end (steel-tipped) resting on a fixed or revolving smoked-glass plate, of which a portion is shown at j in fig. 30.

When its equilibrium is nearly neutral the duplex pendulum forms an exceedingly sensitive level. If the line joining the upper with the lower point of support is not perfectly vertical a very large deflection of the pointer results. It is easy to show mathematically that if the equilibrium were exactly neutral when the line joining the supports was vertical, the apparatus would be unstable should any deflection of this line from the vertical take place, and that when there is some small stability the effect of such a deflection is to cause a large displacement of the bobs. The same characteristic is, however, shared by other neutral or nearly neutral equilibrium seismometers, such as the rolling sphere or the horizontal pendulum.

§ 42. *Duplex Pendulum with a single bob.*

The two bobs of the duplex pendulum may be united to form a single bob, provided we make one of the supporting pieces, preferably that of the upper pendulum, extensible. This idea has been carried out in the instrument shown in Plate X, which was described to the Seismological Society of Japan on Feb. 15th, 1883, by the present writer.

Figs. 31 and 32, Plate X, give sectional elevations of the instrument, in planes at right angles to each other. The bob is a cast-iron ring B, partially supported by the stirrup-shaped piece a, at the bottom of which there is a steel pin b standing in a cup of agate in the lower support s_2. The weight of B is does not all come on this foot-step: the remainder is borne by the spiral spring c which is stretched vertically between the upper support s_1 and the middle of a bar a which crosses the upper surface of the bob.

The apparatus is, in fact, a common and an inverted pendulum combined in one, and its relation to the duplex pendulum is at once evident if we conceive of the bob B as consisting of two parts: one borne by the tension of the spring, the other by the upward thrust of the footstep. These correspond to the two bobs B_1 and B_2 of the last article. The condition giving neutral equilibrium in small displacements is that the thrust of the footstep shall bear to the pull of the spring the same ratio as the length of the inverted pendulum bears to the length of the spring. In other words, the weight of the bob must be shared between its two supporting pieces in proportion to their respective lengths. In practice, to give feebly stable equilibrium, the tension of the spring must be somewhat increased. It is adjustable by the screw d and nut e. The initial strain of the spring is so considerable that any actual displacement scarcely increases the pull it exerts.

To register the motion, an upright multiplying lever f, carried by a gimbal

joint on the fixed bracket g, is connected to the bob at the centre of percussion by a ball and tube joint. At its lower end a light horizontal pointer h is hinged, and projects out horizontally, with its steel-tipped end resting on a revolving smoked-glass plate, as in the instruments already described. The supports s_1 and s_2 are brackets projecting from a post fixed in the ground.

§ 43. *Forbes' Inverted Pendulum Seismometer.*

The writer has only recently become aware of how nearly, in its essential idea, the instrument described in § 42 is a return to a very old seismometer, the invention of the late Principal Forbes. The following account of it, as erected for the observation of earthquakes at Comrie, is taken from the British Association Report for 1841, p. 47 :—

"*The Inverted Pendulum Seismometer.*—(1.) The smallest of the instruments made on this principle has a pendulum thirty-nine inches long, and is fixed into a brass socket at its lower end. The connection between the pendulum and the socket consists of a strong elastic wire, which, by means of a pinching screw, can be either raised or depressed in the socket, so as to increase or diminish the length and sensibility of the pendulum. There is a leaden ball near the top of the pendulum from three to four pounds in weight: it has a hole through its centre so as to allow the pendulum rod to pass freely through it, and it can be fixed at any part of the rod by means of a pinching screw. At the upper extremity of the pendulum there is a soft lead pencil, which rests on an elastic wire contained in a brass tube. The pencil is thus pressed against a white surface of paper, forming the segment of a sphere, having a radius of thirty-nine inches. The paper is pasted on a piece of copper beaten into the proper shape. This copper segment rests on four upright iron rods which are fixed into the base of the instrument. The base consists of four corresponding flat iron bars, which cross in the middle, and support at that point the socket above described, to which the elastic wire of the pendulum is fixed.....The instrument is fixed firmly to the floor of the room where it is set. By means of three adjusting screws, which affect the socket, the upper extremity of the pendulum is brought to the centre of the segment to be marked by it. Any further description of this instrument is rendered unnecessary in consequence of a paper by Professor Forbes, published lately in the Transactions of the Royal Society of Edinburgh, where the mechanism and mathematical properties of it are very clearly pointed out. (2.) The other instrument constructed on this principle has a pendulum ten feet eight inches in length. The spherical segment, on which the vibrations of its point are intended to be marked, is not, as in the instrument just described, supported on upright rods fixed to its base, but is suspended over the pendulum by a strong hold-fast of iron fixed into a wall. In other respects, the mechanical construction of this instrument is much the same as that of the former one."

It has unfortunately been impossible to obtain access, in Japan, to a copy of

the paper in the Edinburgh Transactions, referred to above, but there seems no reason to doubt that the combination of an inverted pendulum with a flexible spring at its base was used to obtain an approach to neutral equilibrium. The bending of the spring in this instrument plays the same part as the inclination of the stretched spring in the seismometer of § 42, in somewhat more than counterbalancing the overturning effect of gravity on the bob when the pendulum is displaced.

Other appliances intended, primarily, to give information about the horizontal movement of the ground during earthquakes will be mentioned in Chapter VI.*

* See also the Appendix.

CHAPTER IV.

INSTRUMENTS FOR OBSERVING VERTICAL MOVEMENT.

§ 44. *Loaded Spiral Spring.*

In attempting to register the vertical component of earthquake movements by the use of a mass whose inertia is to furnish a steady point, we at once meet with the difficulty that gravity acts in the direction in which freedom of motion is be retained. The weight must therefore be borne by some contrivance which, by being extensible, or in some other way, will leave the mass freedom to oscillate in a vertical line. The simplest example is afforded by a mass hung by a long spiral spring from a fixed support. By limiting its freedom to one line we may restrict this apparatus to the measurement of vertical movements, or by leaving it free to oscillate horizontally, like a pendulum, as well as vertically, we may obtain a universal seismometer, which, if furnished with suitable indices, may simultaneously record three rectangular components of the motion. It will generally be found convenient, however, to deal with the vertical component separately, and therefore to deprive the instrument intended to record it of any but vertical freedom.

To make the equilibrium of the hanging mass nearly enough neutral, the spring would need to be of great length, since, when hung directly by a stretched spring, the period of vertical oscillation of the mass will be only that of a simple pendulum whose length is equal to the distance by which the spring is elongated. This, in fact, makes a directly loaded spiral spring almost impracticable as a vertical seismometer.

§ 45. *Horizontal Bar with flexible support and loaded end.*

A committee of the British Association appointed in 1841 "for registering shocks of earthquakes in Great Britain" describe in their report* a seismometer for vertical motion, consisting of "a horizontal bar, fixed to a solid wall by means of a strong flat watch-spring, and loaded at the opposite end. If the wall suddenly rises or sinks, the loaded end of this horizontal rod remains, from its *vis inertia*, nearly at rest, and thus can move any light substance (as paper or a straw) brought against it by the vertical movement of the ground, and which light substance is so adjusted as to stick wherever the rod leaves it." The report goes on to say that an instrument of this kind, set up at Comrie, gave on one occasion a record of vertical movement to the extent of half an inch. Nothing is told as to the period of vertical oscillation of the bar, whose equilibrium was probably too stable to make it act well as a seismometer.

* British Association Report for 1842, p. 94.

§ 46. *Horizontal Bar with stretched supporting spring and loaded end.*

Instead of supporting the horizontal bar by a flat spring at one end, we may simply hinge it at one end to a fixed support, and hold it up by a stretched spiral spring connecting another fixed support above it with some point in the bar, preferably a point not far from the hinge. This arrangement has been used by Mr. Gray, who has also added an ingenious plan by which the equilibrium may be made neutral.*

The attachment of the supporting spring to a point near the hinge gives, of itself, a system possessing much more feeble stability than would be possessed by a mass hanging directly from a spring stretched to the same extent. Thus, in the figure, let a heavy mass be fixed to the rod ABC at C, while the point B is connected with a support D by a spiral spring, and the rod is hinged at A by pressing against a fixed knife-edge. Let n be the ratio of lengths $\frac{AC}{AB}$. We have, in general, for a mass freely executing simple harmonic oscillations, the period $\tau = 2\pi\sqrt{\frac{M}{R}}$, where M is the mass and R is the whole force which tends to restore the mass to its position of equilibrium when its displacement from that position is unity. To apply this to the present case, we may either refer the force to the end of the bar C, where the mass is placed, or refer the mass to B, the point of attachment of the spring. Both processes of course lead to the same result. Taking the latter plan, the mass referred to B is n^2m, where m is the actual mass applied at C. The restoring force for unit displacement (of the point of reference, B) is the force required to produce unit extension of the spring, and is equal to $\frac{nmg}{l}$, where l is the actual total extension.

Hence $$\tau = 2\pi\sqrt{\frac{n^2ml}{nmg}} = 2\pi\sqrt{\frac{nl}{g}},$$

which is greater in the ratio $\sqrt{n} : 1$ than the period in which a mass would oscillate if directly hung to the spring, and stretching it to the same extent. The arrangement has therefore the advantage of giving more nearly neutral equilibrium than is attained by the use of a directly loaded spring of the same length. On the other hand, the effective inertia of the system is n times less than it would be if the spring were equally drawn out by a weight directly applied to it.

* Transactions of the Seismological Society of Japan, Vol. III, p. 137.

The addition which Mr. Gray has made, with the view of making the equilibrium still more nearly neutral, is a trough or tube containing a liquid, which is connected to the horizontal bar in such a manner that when the bar is depressed the liquid moves in the tube so as virtually to increase the load on the bar, and when it rises the liquid moves so as virtually to decrease the load. The apparatus is shown in sectional elevation in Plate VII, fig. 33, which, with the following description, is taken from the Philosophical Magazine for Sept. 1881, p. 209:—

"A vertical spring S is fixed at its upper end by means of a nut n, which rests on the top of the frame F, and serves to raise or lower the spring through a short distance as a last adjustment for the position of the cross-arm A. The arm A rests at one end on two sharp points, p, one resting in a conical hole and the other in a V-slot; it is supported at B by the spring S, and is weighted at C with a lead ring R. Over a pin at the point C a stirrup of thread is placed which supports a small trough t. The trough t is pivotted at a, has attached to it the index i (which is hinged by means of a strip of tough paper at h, and rests through a fine pin on the glass plate g), and is partly filled with mercury.... When the plane carrying the spring S is raised and lowered, the point a rises and falls, but in consequence of the inertia and slow period of R the point C remains behind. In consequence of this the end of the trough t falls and rises relatively to a; and the mercury, running backwards and forwards, puts more or less force on the point C, and hence tends to keep this point stationary."

An objection to this arrangement is that horizontal oscillations of the ground produce a heaping up of the liquid at one and the other end of the tube alternately, and so throw the bar into a state of forced vertical oscillation.

§ 47. *Astatic Horizontal Bar, without liquid.*

A simpler and equally effective method of reducing a loaded horizontal bar to approximate astaticism, the invention of the present writer,* is as follows:— Instead of changing the load upon the bar, when the bar rises or falls, we may change the leverage at which the spring acts. The moment of the weight is balanced, about the fulcrum, by the moment of the upward pull of the spring. In any small displacement the moment of the weight is sensibly constant. For neutral equilibrium we must therefore make the moment of the pull of the spring constant. To do this we must cause the point at which the spring is attached to the bar to move towards the fulcrum when the spring lengthens, and away from the fulcrum when the spring shortens. This is easily done by putting the point of attachment B (in the sketch on p. 48) not in the horizontal line joining A with C, but at a distance v vertically below that line. Let h be the horizontal distance of the spring's line of action from the fulcrum A. Then if we suppose the bar to be displaced downwards through any very small angle $d\theta$ from its normal horizontal position, the point of attachment of the spring goes vertically

* Trans. of the Seismological Society of Japan, Vol. III, p. 140.

down through a distance $hd\theta$, and horizontally towards the fulcrum through a distance $vd\theta$.

Now if we call l the total elongation of the spring in the normal position of the lever, it follows from Hooke's Law that the upward pull is increased (by the supposed displacement) in the ratio

$$\frac{l + hd\theta}{l};$$

and the leverage at which this acts is diminished in the ratio

$$\frac{h - vd\theta}{h}.$$

To make the system astatic, the product of the pull into the leverage is to be constant, being equal to the moment of the weight, and hence we must have

$$lh = (l + hd\theta)(h - vd\theta).$$

From this, neglecting the term involving $d\theta^2$, we have

$$v = \frac{h^2}{l},$$

an equation which determines the distance v below the horizontal line of the bar, at which the pull of the spring is to be applied, to give neutral equilibrium for infinitesimally small displacements. In practice, v must be made somewhat less than this, to leave a small margin of stability.

§ 48. *Actual Vertical-Motion Seismograph.*

An actual vertical seismograph designed on this plan, and erected in the writer's observatory, is shown on Plate XI, where fig. 34 gives a side elevation, fig. 35 a front elevation, and fig. 36 a plan. The whole is supported on a post P, stuck in the ground. The horizontal bar is a stout brass plate a loaded at the outer edge with a cylinder of lead b. Close to the edge of a nearest to the post a conical hole and V-slot are cut, as far apart from each other as the width of the plate will allow; and into these a pair of steel points cc, fixed to the post, press. These points determine the horizontal axis about which the plate is free to rotate. A pair of springs dd are used to hold up the weight: the lower ends are connected by the hanging bar e, at the centre of which there is a conical hole against which the screw f in the plate a presses. This part of the apparatus is separately shown in fig. 37, which gives a transverse section through the plate a, in the plane of the springs and the hanging bar. The depth of the point of f (the point, that is, where the pull of the springs acts) is adjustable by turning the screw, and it is secured at any position by the jam-nut g. The upper ends of the springs are fixed to a board h, whose position is determined and whose height and plane are adjustable by three screws iij, in a manner readily intelligible from the figures.

The steady line of the system (the instantaneous axis with respect to a vertical displacement of the axis of support) lies, of course, a little way outside the centre of the bob b. At that line a pin k is fixed to the plate a, which gears into a slot

in the cranked multiplying lever *l*. This lever is hinged about a fixed horizontal axis at *m*, its bearings being carried by a bracket *n* standing out from one side of the post. The longer part of the lever is of straw; and its lower end carries a hinged marking pointer whose motions are recorded on the smoked-glass plate *o*. The multiplying ratio is 7 to 1.

In this instrument it is scarcely practicable to keep the glass plate revolving continuously. Changes of temperature and other causes make the pull of the springs so variable that the equilibrium position is rarely constant for any long time, apart from earthquake disturbance. For the same reason static records are useless; and the plan is adopted of starting the plate into rotation as early as possible in the disturbance, by making the earthquake close an electric circuit which releases a catch and allows a driving clock to come into action. The arrangement will be described in a later chapter.

The bob *b* might of course be pivotted at the instantaneous axis of the plate, instead of being fixed to the plate: but, as its diameter is small compared with its distance from the axis of support, we should gain little, in the way of steadiness, by this complication. The mass of the multiplying lever is very small; otherwise we should place above its hinge *m* a counterpoise which would raise its centre of gravity to the horizontal plane containing the hinge, in order to prevent a horizontal displacement of the ground from producing any motion of the system.

§ 49. *Hydrometer Vertical-Motion Seismograph.*

A proposed instrument is described by Mr. Gray under this title, in the Philosophical Magazine for Sept. 1881. An enlarged hydrometer, with a narrow projecting end, is immersed in a liquid, and weighted to have a slow period of vertical vibration. It is constrained to move in a vertical line only, and the projecting end is connected to a marking index.*

The same observer has also attempted to register the vertical motion during earthquakes by using a metallic vessel with a corrugated bottom, filled with liquid which can oscillate vertically on account of the flexibility of the bottom of the vessel.

Both of these arrangements are unquestionably much less practicable than the loaded horizontal bar, rendered nearly astatic either by Mr. Gray's or the present writer's method, and they may therefore be passed over with the briefest mention.

* A buoy, free to sink and rise in a tub of water, had been previously used as a vertical-motion seismometer by Dr. G. Wagener. (Trans. Seis. Soc. of Japan, Vol. I, p. 61.)

CHAPTER V.

RESULTS OF OBSERVATIONS.

§ 50. *Static Records.*

Previous to the first publication of the writer's seismometric observations *, no observer had (so far as he is aware) succeeded in effecting a measurement of the magnitude and direction of the ground's motion, in conjunction with the time, during any prolonged earthquake. Such measurements as had been made were, almost without exception, of the static kind, into which the consideration of time did not enter. The information which static records can yield is imperfect in a very important particular. A knowledge of the direction and magnitude of earthquake motions does not suffice to enable us to estimate the energy and destructive power of the disturbance, since these things depend, most directly, on the relation of displacement to time. And it may fairly be added, that no static record can determine conclusively even the amplitude of an earthquake vibration. If the seismometer has much stability, its oscillations may become great enough to exceed and altogether mask the true earthquake motion; unless, indeed, there is much friction, in which case the records will be too small. On the other hand, if the equilibrium of the seismometer is nearly neutral, it will be liable, during a disturbance consisting of many successive waves, to work gradually away from its original position, and so to give a record which is greatly in excess of the amplitude of any single movement.

It would be scarcely possible, and not at all profitable, to give a full account of the early static measurements of earthquakes. The observations made by Mr. Knipping in Tokio with Dr. G. Wagener's pendulum seismometer have been already alluded to (§ 36). These, and also the earlier observations of Dr. Verbeek (§ 31), were valuable as showing that the amplitude of motion in ordinary earthquakes is so exceedingly small that a considerable multiplication is indispensable in the recording apparatus; and at the same time that it is needless to let the steady mass be free to move, or be in neutral equilibrium, throughout more than a very small range of positions.

In an account of a somewhat destructive earthquake felt in Tokio and Yokohama in February 1880†, Mr. Milne gives some static records, which he obtained by means of a long pendulum, without multiplication. The curves are very irregular and not easily intelligible; they show pretty clearly the comparatively

* Transactions of the Asiatic Society of Japan, Vol. IX, p. 40 (Dec. 14, 1880).
† Transactions of the Seismological Society of Japan, Vol. I, part 2.

rapid undulations of the earthquake superposed on larger displacements which are presumably due to the swinging of the pendulum. Mr Milne also gives results obtained with another long pendulum, which had two pointers writing without multiplication on strips of smoked-glass, which were set in motion by the disturbance, and were caused to move under the pointers for a time estimated at 3 seconds. During this time short portions of two undulating curves were traced; but the amount of displacement shown was too small to admit of exact measurement, and the time included by the records was probably not more than a fiftieth part of the whole duration of disturbance.

A remarkable series of examples of static records has been furnished by the observations of Father Faura at Manila during the great earthquakes of July 14th to 25th, 1880. These records, taken by a common pendulum writing in lycopodium dust without multiplication, will be found described and figured in the Proceedings of the Royal Society of London, Vol. XXXI, p. 460. Nothing is said as to the scale of the figures, which are probably much less than full-size.* In the description which accompanies them the amplitudes of horizontal motion are stated only in terms of the angles of inclination made by the pendulum, but its length is not given. Strangely enough, the writer appears to suppose that the inclination of a vertical pendulum during an earthquake is a measure of the *slope* of the surface of the ground, when that is horizontal before disturbance. The diagrams are very complicated, and it is impossible to make out, by inspection of them, how much of the recorded displacement is a true motion of the ground, and how much is due to the swinging of the pendulum.

§ 51. *Records on continuously moving plates.*

The present writer was enabled, through the liberality of the President of the University of Tokio, to establish a seismometrical observatory there in 1880. The instruments originally erected were the long pendulum with two multiplying pointers (§ 37), and the horizontal pendulum, or rather pair of horizontal pendulums (§ 23), also with multiplying pointers. In both cases, plates driven with a continuous motion by clockwork were used to receive the records, the writer having been early convinced of the almost complete uselessness of static records. A number of the other instruments described in Chapters II, III and IV have been added, but most of the records hitherto obtained have been given by the horizontal pendulum, in one form or another. From the establishment of the observatory to the present time a very large number of earthquakes have been recorded, out of which a few typical examples have been selected for description, and are given below. Plates XII to XX are *fac-simile* reproductions of photographs taken from the smoked-glass plates on which records were automatically inscribed.

* A diagram of the Manila earthquake, which is the same as the fig. 2 of the Royal Society account, will be found in the *Japan Weekly Mail* of Aug. 14th, 1880. If this is (as it appears to be) a *fac-simile* of the pendulum record, the Royal Society diagrams must have been reduced in the proportion of about 1 to 2½.

§ 52. *Earliest Records.*

The following account of the earliest earthquake record obtained by the writer is taken, with little alteration, from a paper entitled "Notes on Some Recent Earthquakes," published in the Transactions of the Asiatic Society of Japan, Vol. IX, p. 40. This was nothing more than a feeble shock, which did no damage to buildings, and was just such as residents in Tokio expect to occur at intervals of a few days.

Earthquake of Nov. 3rd, 1880, 5 h. 45 m. A.M.—Record given by the Horizontal Pendulum Seismograph.

One pointer registered East-West motion, the other North-South motion. The glass plate of this instrument was revolving at the rate of one turn in thirty seconds, and the record extended over three complete revolutions. In other words, the earthquake lasted continuously during one and a half minutes of time. During this time no fewer than 150 complete (double) oscillations of the earth's surface took place. The mean period of a complete oscillation was, as nearly as possible, three-fifths of a second. The motion was almost wholly North-South; the other pointer showed a very small, though perceptible, amount of disturbance. The records given by both pointers began simultaneously, as far as can be judged, but the East-West movement soon ceased, while the North-South movement lasted, as has been said, for 1½ minutes, and consisted of more than 150 waves.

The earthquake did not begin suddenly. The waves began to appear so gradually that it was impossible to say to which side the first deviation took place. The amplitude increased, however, pretty rapidly, and reached a maximum after about three complete waves. Allowing for the multiplication introduced by the recording lever (6 to 1, in this case) the greatest displacement of a particle on the earth's surface was 0·29 mm. in a direction approximately North and South, and 0·05 mm. in a direction approximately East and West. The two together gave a motion of about 0·30 mm. in the direction N. 15° W. and E. 15° S.

Both in amplitude and in period the successive waves were far from regular. The disturbance did not consist of a series of simple harmonic displacements.

After about the third wave from the beginning of the disturbance the amplitude of motion ceased to increase. It then fluctuated considerably, sometimes becoming almost inappreciable, and again increasing to a value approaching its first maximum. Before the earthquake ceased there were several maximums and minimums in the amplitude of motion, but never a complete cessation until the whole disturbance was over.

Record given by the Long Pendulum Seismograph.

This record showed that the pendulum was set swinging by the shock through a distance of about 1 mm: and as the swinging continued with gradually diminishing amplitude during many revolutions of the plates, the records were much obscured. It was, however, easy to see the comparatively rapid undulations

of the earthquake superposed on the long-period waves due to the swing of the pendulum. The greatest actual displacement registered by the North-South motion pointer was two-sevenths of a millimetre: the other pointer showed no more than a trace of motion. These results agree very closely with those given by the other instrument.

If we assume the greatest displacement to have taken place approximately according to the simple harmonic law, then, taking the period as 0.6 second and the total range of motion as 0.3 mm., we find for the greatest velocity 1.57 mm. per second, and for the greatest rate of acceleration 16.4 mm. per second per second. The value of g in the same units is 9797. Bodies connected to the earth's surface sufficiently rigidly to move with it must therefore have experienced, in the earthquake, a maximum horizontal force equal to about $\frac{1}{600}$ of their own weight.

After describing (in the same paper) the records of four other small earthquakes which also occurred during the month of November, 1880, the writer drew attention to the following as the most striking features of these early observations:—"(1) The very gradual beginning and ending of the disturbance. In none of the observations did the maximum motion occur until after several complete oscillations had taken place. (2) The irregularity of the motion. The successive undulations are widely different both in extent and in periodic time. (3) The large number of undulations in a single earthquake, and the continuous character of the shock. (4) The extreme minuteness of the motion of the earth's surface."

§ 53. *Earthquake of February 7th, 1881.**

Plate XII is the record of a small earthquake, given by the horizontal pendulum seismograph (of the form described in § 23). On this occasion the displacement appears to have been confined to one direction, (approximately East-West): for this reason the tracings made by one pointer only are reproduced in the Plate. The glass plate of the instrument made one revolution in 104 seconds, and the multiplying ratio was 6 to 1. The visible disturbance begins at the point a, at the top of Plate XII. The innermost of the two circles visible on the Plate is that which the pointer was tracing out prior to the earthquake: on it, at a, a feeble undulation will be seen to begin, and continue in the direction of the arrow, which is drawn opposite to the direction in which the plate was revolving. It is not until about twenty-five seconds, or nearly a whole quadrant of the glass plate from the beginning of visible motion, that the displacements become at all considerable. The greatest motion occurs at b (at the bottom of the Plate). At that point the motion from one side to the other is 6 mm. on the record, corresponding to 1 mm. of actual horizontal motion of the ground.

The undulations continue with varying amplitude for about $1\frac{3}{8}$ complete revolutions of the plate. The latest motion which can be seen on the record

* See also Trans. of the Seismological Society of Japan, Vol. III, p. 115.

occurs at the point c on the outer circle. The outer circle is the line traced by the pointer after the cessation of the disturbance.

It must not be supposed that the want of coincidence between the circles traced before and after the earthquake is evidence of a permanent displacement of the ground, since during a prolonged disturbance the accumulated effects of frictional forces are almost sure to produce some resulting motion of the so-called steady line, especially when the equilibrium is nearly neutral.

This record exemplifies very well the characteristics mentioned at the end of the preceding paragraph. The motions are at first so small that it is difficult to point out the beginning definitely, and the undulations die out so gradually that it is equally difficult to determine the end. Again, though the amplitudes are far from regular, we cannot point to any one displacement as the principal shock.

At b, where the motion is greatest, the displacement (from West to East) is 6 mm. on the record, that is 1 mm. of actual earth motion. The motion there is not very far from being simple harmonic, with a period of 1.4 sec. This gives a maximum velocity of 2.3 mm. per sec. and a maximum acceleration of 9.6 mm. per sec. per sec., or say $\frac{1}{1000}$ of the acceleration due to gravity. In registering earthquakes such as this, the necessity of avoiding friction in the seismometer will be apparent (§ 38).

§ 54. *Earthquake of March 8th, 1881.**

Plate XIII is the record of this earthquake, which was one of unusual violence compared with the minute disturbances to which residents in Tokio are accustomed.

The record, which is in some respects the best the writer has obtained of any earthquake, was given by the horizontal pendulum seismograph of § 23. The multiplying ratio was again six to one. Of the two records on Plate XIII, the inner is N-S motion, the outer E-W motion. The cross lines d and d' show the distance measured circumferentially between the marking ends of the two pointers. One revolution of the plate corresponds to about 80 seconds of time. The beginning of motion is at a on the E-W circle (at the top of the Plate). At a', which is the corresponding point on the N-S circle, and for some time later, scarcely any displacement occurs. The earliest considerable N-S motion is at b, which is synchronous with the E-W displacement b'. Midway between a and b there is a considerable E-W motion which has nothing to correspond with it on the N-S circle.

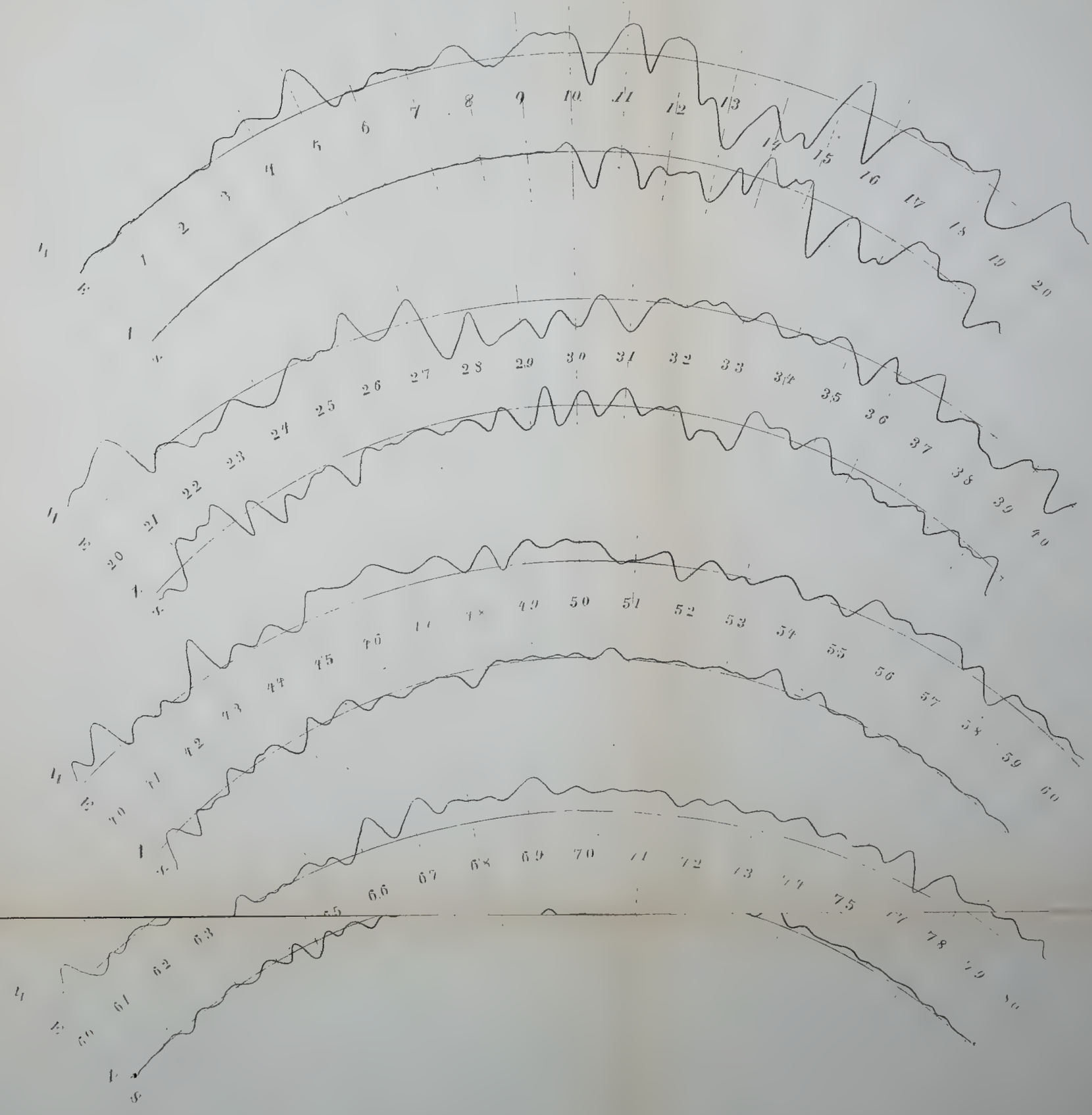
The most violent motions occur a little later than the points marked b and b'. The record extends over nearly two complete revolutions of the plate, up to the point c in the outer circle, where it will be observed to leave off abruptly. This is because the writer, who had the good fortune to be present in the observatory during this earthquake, withdrew the plate at the point marked c, in

* See also Trans. of the Seismological Society of Japan, Vol. III, p. 121.

Earthquake of March 8th 1881. (Tokio)

The motion is magnified six times.

The numbers denote Seconds of time.



order to prevent confusion by the superposition of the later feeble undulations on the earlier important ones. The point c', in the inner circle, corresponds to c in the outer. By the time the plate was removed the disturbance had lasted for about $2\frac{1}{2}$ minutes, and nearly 200 waves had been registered. Feeble movements were perceptible for some time longer.

The earlier and more interesting part of the record is copied in the accompanying figure (inserted here for convenience of reference). There the circular path traced by each pointer has been cut up into four arcs, each of which corresponds to 20 seconds, and radial lines have been drawn to mark intervals of one second. The four arcs are consecutive. They begin at the point where the motion was first visible (the point *a* of Plate XIII). Each portion shows a pair of records traced by the two pointers, and the lower one is turned round so that contemporary points in the two lie on the same radius. Much care has been taken to verify, by direct measurement of the glass plate, the coincidence in time of the points here shown as coincident, since measurements made on the paper photographs are liable to error on account of the unequal contraction of the sheet in drying. The circular path which was being traced by each pointer before the earthquake is shown in the figure by a faint line.

Up to the tenth second the motion is almost wholly E-W. Then a large N-S component comes in, and this continues to be present during the remainder of the earthquake, except near the end of the record (as it appears on plate XIII), where it will be seen that the N-S motion dies out sooner than the other.

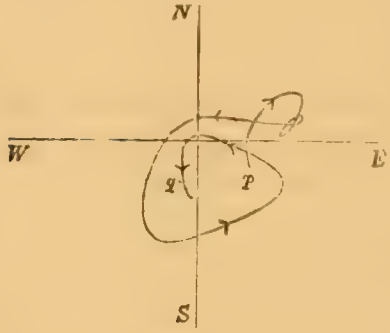
Perhaps the most interesting feature of the record is the varying relation of the W-E and N-S motions during the disturbance.

At first, for nine seconds, one occurs alone. From the tenth to the thirteenth second there is synchronism between them; during that time displacements toward E. and S. are contemporaneous. A little later, about the thirtieth second, there is an equally distinct synchronism; but this time motions towards E. and N. are contemporaneous:—there has been a change of phase-relation amounting to just half a complete oscillation. In general, in other parts of the record it is impossible to trace any distinct relation between the two components. For instance, in the twenty-eighth second there is a notable movement from West to East which is not associated with contemporary displacement of the other pointer. The same remark applies to the forty-third second, and to the seventy-sixth.

Towards the end of the earthquake this independence of the two components of motion was very clearly seen by the writer, who noticed that one pointer sometimes moved vigorously while the other was nearly at rest, whereas a few seconds later the pointer formerly at rest took up the motion, and the movement of the other almost ceased.

This change of phase-relation in the two components is evidence, of course, that the direction of movement of the ground was continually varying during the disturbance. In some parts this variation occurred so rapidly as to make the path of a surface-particle very far from rectilinear.

A remarkable instance of this occurs during the sixteenth second, when the amplitude of motion was it its maximum. The W-E component was then almost exactly a quarter of a period on advance of the N-S component, and hence, when compounded, the two records show the motion of the ground to have consisted, at that time, of rotation in a very roughly circular path. The annexed figure is the path determined by compounding the two records during three seconds, (from the time 13·7 sec. to 16·7 sec., measured from the beginning of the earthquake). The path described in this interval begins at p and ends at q.



The displacements plotted in this sketch are taken without change of scale from the record, and hence the scale of the sketch is six times full size.

The greatest single horizontal displacement (from one side to the other) is about 25 mm. on the record, which corresponds to nearly 4·2 mm. of actual motion. The greatest velocity of horizontal movement of a surface particle was nearly 10 mm. per sec. It is difficult to find the greatest rate of acceleration from the record, on account of the very irregular character of the motion: it appears to have been from 40 to 50 mm. per sec. per sec., or about $\frac{1}{200}$ of g. The period of the largest single complete oscillation (that which occurred at 15 seconds from the beginning) was 1·1 seconds.

It may be added that this period was unusually long, which accounts for the fact that, notwithstanding the large amplitude of motion, this earthquake was not of a destructive character. Although alarming enough, it did no damage except cause some cracks in walls.

§ 55. *Earthquakes of March 1st, 1882.*

Two earthquakes which occurred on March 1st, 1882, of which the second was unusually sharp, though not destructive, are shown in Plate XIV, which is the record given by a single horizontal pendulum, of the form described in § 25. The record gives only the West-East component of the horizontal motion: the pointer which should have registered North-South motion was unfortunately out of order, and failed to do more than show that a considerable amount of N-S movement had also taken place.

Here the plate made one revolution in 85 secs., and the multiplying ratio was 7 to 1. Of the two circles which appear close together in the record, the outer is the path traced before the first earthquake, and the inner is the path traced after the second.

The earliest visible motion is a tremor of short-period waves, which appears on the outer circle at a. Following the record in the direction in which it was deposited (the direction shown by the arrow), we see these short-

period waves appearing very faintly at intervals, and these appear to comprise the whole record of the first earthquake.

The second and relatively large shock, which occurred about two hours later, also begins in a tremor of short period waves, which become very prominent at *b*, although they may be detected for some time before that point is reached. In a few seconds more these develop into large motions of much longer period. The greatest displacement is at *c*, where a lurch from E. to W. measures 35 mm. on the record, corresponding to 5 mm. of actual earth motion. A little later an interval of comparative rest occurs; but violent motions begin again at *d*. The disturbance continues irregularly, and with gradually diminishing amplitude, for nearly $1\frac{2}{3}$ revolutions more. The last trace of visible motion is at *e* on the inner circle. The second record extends over fully 2 revolutions in all, showing that the earthquake lasted for three minutes.

The short-period waves with which the earthquake begins are present, more or less, during one minute. At first they exist alone. Then they may be traced superposed on the great movements which constitute the principal shock. But in the later parts of the record, during the gradual dying out of disturbance, they do not appear: the motion then consists entirely of long period waves.

The short-period waves at the beginning and during the early part of the earthquake have a period of only 0.17 sec., and their amplitude is no more than a very small fraction of a millimetre. The greatest back and forth motion, at *c*, occupies about 0.8 sec. As the disturbance ceases the average period of the undulations appears to increase.

The record is, as has been said, incomplete, inasmuch as it gives only one component of the horizontal displacement. Independent evidence showed, however, that the component given here was the principal part of the motion. For a rough estimate of maximum velocity and acceleration in the East-West direction, we may take the motion at *c* as a simple harmonic displacement with period 0.8 sec. and amplitude 2.5 mm. This gives a maximum velocity of 19.6 mm. per sec.; and a maximum acceleration of 154 mm. per sec. per sec., or $\frac{1}{64}$ of *g*.

§ 56. *Earthquake of March 11th, 1882.*[*]

Ten days later than the earthquake just described, another occurred, of sufficient violence to do a small amount of damage to buildings, by overturning chimneys and cracking walls. A record of this shock, obtained by a pair of horizontal pendulums of the cone-bob form (described in § 24), is given in Plate XV. The inner pointer was placed somewhat obliquely to the radius of the plate, which accounts for the skew character of its markings. It registered E-W movement, and the outer pointer N-S movement. Previous to the occurrence of the earthquake, the circular path traced by the outer pointer had become so wide

[*] See also Trans. of the Seismological Society of Japan, Vol. IV, p. 73. In that paper the multiplying ratio used in obtaining this record was inadvertently given as 3 to 1, instead of 4 to 1.

as partially to obscure the record. The multiplication was 4 to 1; and one revolution of the plate took 88 seconds.

The earthquake began, as usual, with very small motions, at or near the place marked a in the inner circle and a' in the outer. (The circumferential distance between the ends of the two pointers is shown by the simultaneously inscribed lines b and b'). After a few seconds, at c and the contemporary point c', the motion became suddenly violent, and, though the earthquake lasted for a long time, the displacements which occurred at c and c' were not exceeded or even equalled during the remainder of the disturbance.

The record covers more than three revolutions, showing that the earthquake continued for at least $4\frac{1}{2}$ minutes. The greatest single displacement (at c) from E. to W. is 21 mm. on the record, or 5.25 mm. of actual motion. Contemporaneous with this is the greatest S. to N. displacement (at c'), which is 18 mm. on the record, or 4.5 mm. of actual motion. Combining these, we find that the greatest single movement of the ground was 7 mm., in the direction N.W., nearly. This is the return which followed the first great displacement, whose direction was nearly S.E., and whose amplitude was somewhat less than that of the return.

At this point the period was about 0.7 sec. A simple harmonic oscillation with this period, and 3.5 mm. amplitude, gives a maximum velocity of 31 mm. per second, and a maximum acceleration of 280 mm. per sec. per sec., or $\frac{1}{35}$ of g.

The period of vibration lengthens towards the end of the disturbance; and at the beginning there are traces of short-period waves preceding as well as superposed on the principal movements.

§ 57. *Earthquake of March 19th, 1882.*

Plate XVI gives the record of another earthquake, which came in the same month as the shocks described in the two preceding paragraphs, and was registered by the seismograph of § 24. This was a less severe, but very long continued disturbance. The East-West record (the outer of the two) was somewhat obscured by a broadening of the circle traced prior to the earthquake. The disturbance extends over just three complete revolutions of the plate, and the end overlaps the beginning in a way which makes it almost impossible to distinguish the beginning or the end.

The multiplying ratio was 4 to 1; and one revolution of the plate occupied 78 seconds. The greatest displacement is about 2 mm. The mean period, during the early part of the disturbance, is somewhat less than 1 sec., but this increases very much towards the close.

§ 58. *Earthquake of August 18th, 1882.*

The record of this somewhat sharp shock is shown in Plate XVII, in which the multiplying ratio is 4 to 1. The motion was principally E-W, and the pointer registering that component happens to have been set somewhat

obliquely to the tangent of the circle it drew. The lines c and c' serve to show the relative positions of the pointers. The first visible disturbance is at a (on the inner record). The record extends over about two revolutions. This is an excellent example of the presence of short-period vibrations of small amplitude in conjunction with larger and slower motions. The largest displacement, at b, measures 4.25 mm. when reduced to the natural scale.

§ 59. *Earthquake of September 29th, 1882.*

A moderate earthquake of the above date illustrates well the arrival of short-period vibrations in advance of the principal movements. Plate XVIII shows the record, which consisted almost wholly of E-W motion. It began at a and was traced in the direction of the arrow. From a to b nothing appears but a ripple of minute short-period waves. The greater motions, which begin at b, have at first short-period waves mixed up with them; but these disappear after a time, and the earthquake dies out in relatively long-period waves only.

In this case the early part is shown with unusual clearness, owing to the fact that previous to the shock the pointer was held by friction somewhat inside of its position of equilibrium, and consequently the first shaking caused it to creep outwards from the centre.

The multiplying ratio was 6 to 1, and one revolution of the plate took 69 seconds.

§ 60. *Earthquake of April 23rd, 1883.*

A sharp and long continued shock (followed by another slighter shaking about ten minutes later), which occurred at 10.35 p.m. on April 23rd, 1883, is recorded on Plates XIX and XX. Plate XIX is the record given by the horizontal pendulums of § 24, with a multiplication of 4. One revolution of the plate took 54 seconds. The shaking lasted so long as to make it impossible to follow all the motions, but the principal part of the disturbance is very clearly shown. The earliest visible motion is at a on the E-W circle. At b, nine seconds later, the motions suddenly become large. The corresponding part of the N-S record is b'. The record covers five revolutions of the plate, or $4\frac{1}{2}$ minutes of time.

Plate XX is a very remarkable record of the same earthquake, given by the long pendulum instrument of § 37, with one pointer free to move in any azimuth, and having a multiplication of 10. The plate revolved once every 72 seconds. Nothing could show more clearly than this does the extraordinary irregularity of earthquake motion. In fact, it is impossible to apply the terms used in speaking of regular undulations to the spasmodic twists and wriggles which the surface of the earth here executed.

In Plate XX the direction of motion of the plate under the pointer was E.30° N. The principal movements are at the place marked c, and these correspond to the records given by the horizontal pendulums at b and b' on Plate XIX.

It is interesting to compare the records of the principal movements given by the two instruments, and for this purpose the two components on Plate XIX have been combined.

It must be borne in mind that the diagram, as lithographed from a photograph, bears to the original tracing on the plate the relation of a *mirror image* to its object, and therefore the directions N.E.S.W. follow each other counter-clockwise instead of clockwise.

Lines, numbered 1, 2, 3 etc., have been marked on the two components of the horizontal pendulum record, to show corresponding instants of time; and these lines are drawn (by means of a template) so that each is the path which the corresponding pointer would have described if it had been caused to oscillate while the plate stood at rest. Earthquake displacements are therefore to be measured along them.

It will be seen at once that the phases of the two components do not agree, in other words that the motion of the ground is not rectilinear. The actual path of a surface particle, got by carefully compounding the displacements as determined by Plate XIX, from the points numbered 1 to 16, is shown in the upper figure in the centre of Plate XX. To make it immediately comparable with the long pendulum record it is, however, magnified two and a half times, so that it bears to the earth's motions the ratio of 10 to 1. The path begins at the origin and is traced in the direction of the arrow heads: it ends at a point corresponding to the points numbered 16 in Plate XIX. The time taken to trace this path was 3·7 seconds.

The lower figure in the centre of Plate XX is a *fac-simile* of the record given by the long pendulum during the same interval: it is inverted so as to form a true *fac-simile* and not a mirror image. Its scale is also ten times full size. The line marked on it E. 30° N. is the direction of movement of the plate under the pointer. Hence the lower diagram ought to agree with the upper one, if we suppose the upper one to be stretched out at a uniform rate, during the time of its being described, in the direction W. 30° S.—the direction shown by the dotted line in the upper figure.

An inspection will show that the agreement between the two records is very satisfactory, if we make allowance for slight movements on the part of the "steady point", which, in such a violent disturbance and during so considerable an interval, are in fact almost inevitable. By compressing the lower figure along the tangent to the circle we get a path very similar to that in the upper figure. The two instruments which gave the records here compared are so different in all respects that the agreement of the records, when thus examined, affords very strong evidence of the substantial accuracy of both.

The greatest range of actual earth movement in this case was 5 mm. The greatest vertical motion was less than 1 mm. The movements were so far from cyclic that we cannot, except very loosely, speak of their period. For the principal movements it was about 0.8 sec.

A record of the same earthquake, given by the duplex pendulum (§ 41) on a stationary plate, with a multiplication of 3.5, is shown in the centre of Plate XIX. Near the origin the motions are so numerous and so various in direction that a considerable area of the lamp-black has simply been cleaned off, and it is only the more prominent motions that are traceable. The prominent part of the figure, however, agrees very closely with the path shown by the other two instruments for the same portion of the motion, and so gives additional evidence of the accuracy of the records.

§ 61. *Summary of results.*

The examples which have been given are fairly representative of a much greater number of records, obtained during two and a half years. In the great majority of cases, however, the motions have resembled the smaller rather than the larger of the earthquakes here cited. In very many instances the recorded displacements are too small to admit easily of reproduction.

The following conclusions may be taken as established, with respect to the earthquakes which occur with much frequency in the Plain of Yedo.*

(1). In almost every instance the motion of the ground begins very gradually, and at least some seconds pass before it reaches its maximum. This makes it impossible to determine accurately the time of occurrence of an earthquake by means of a mechanical or electrical clock-stopping or time-taking apparatus, since the time so determined will be dependent on the sensibility of the apparatus to disturbance.

(2). An earthquake consists of many successive movements, and there is, almost always, no single large one which stands out prominently from the rest. As a rule there are many movements of nearly equal range, and sometimes several maximums, with intervals of comparative rest between.

(3). The disturbance ends even more gradually than it begins. The motion of the ground dies out in a long series of undulations with irregularly diminishing amplitudes.

(4). The range, the period, and the direction of movement are exceedingly and irregularly variable during any one earthquake.

(5). The duration of disturbance of the ground is rarely less than one minute, and often several minutes.

(6). Even in somewhat destructive earthquakes the greatest displacement of a point on the surface of the soil is only a few millimetres, and there are very many minor earthquakes in which it is less than one millimetre.

(7). In many cases the beginning of visible motion consists of a tremor of

* The writer's observatory is situated on one of the lowest parts of the great alluvial plain which forms the site of the city of Tokio. It stands at a considerable distance from any elevated ground. Water, in abundance, is reached about one metre below the surface. The walls of the building which contains the seismographs are light wooden structures placed on the surface, without any foundations to disturb the continuity of the ground inside and outside.

short-period waves of small amplitude, which are followed by the principal movements. Often the early principal movements carry, superposed on them, small short-period waves. These generally disappear before the end, and the earthquake as it dies out consists of long-period waves alone. The first tremor and the subsequent large movements sometimes occur in a manner strongly suggestive of the idea that the first, or short-period movements, are normal waves and the second, or principal movements, are transverse waves (§ 2).

(8). A progressive, though irregular, lengthening of period can sometimes be detected towards the close of the disturbance.

(9). The period of the principal movements is usually from half a second to a second; but the short-period waves which occur at the beginning may have a frequency of 5 to the second, or more.

(10). The vertical motion is generally much less than the horizontal.

§ 62. *Complexity of the motion.*

The long duration and great complexity of the movements which the surface of the ground performs during an ordinary earthquake in Tokio are no doubt largely due to the (presumably) considerable distance of the observing station from the origin of disturbance. The theoretical considerations which have been adduced in Chapter I lead us to expect that (except as regards amplitude of motion) earthquakes grow as they travel through heterogeneous media; and observations of the same shock at different places show that this does happen.

In a paper descriptive of the earthquake of March 8th 1881,* which supplied the earliest clear evidence of change in the direction of movement during a disturbance, the present writer has suggested various explanations of this change. These are: (1) the presence of normal and transverse waves together. Even transverse waves alone may give non-rectilinear movements (§ 1), whose horizontal components may also be curved provided the plane of the wave is not vertical. (2) A possibly wide and not very distant origin, giving waves with various azimuths. (3) The reflections, refractions, and diffractions which occur along the route. (4) The possible simultaneous, or nearly simultaneous, occurrence of two or more separate earthquakes. This last explanation is not so extravagant as it may at first sight appear to be, if we consider that in a district liable (as the Plain of Yedo is) to frequent earthquakes, there must often exist states of critical equilibrium, ready to act as centres of earthquake disturbance. The vibrations of a shock occurring at one point might therefore, on reaching one of those places, start another convulsion, which would add its effects to those of the first on neighbouring parts of the soil.

It appears, however, that changes in the direction of movement during an earthquake are usual rather than exceptional; and they must therefore be ascribed, in general, to the first three of the causes named above—probably to the first and third in the great majority of cases.

* Trans. of the Seismological Society of Japan, Vol. III, p. 121.

The non-rectilinear character of the motion, which can be deduced (as has been done above) by compounding two rectangular components of the horizontal motion when these are separately recorded, is most directly shown by seismographs possessing two degrees of horizontal freedom and giving records of which Plate XX is an example. Even in very small earthquakes the indices of these instruments frequently exhibit an immense number of movements in all possible azimuths; so much so, that if the smoked-glass plate forming the record receiver is stationary, the lamp-black is sometimes completely rubbed off throughout a small area surrounding the point at which the index stands when at rest. The writer has been close to the duplex pendulum seismograph (§ 41) when a small (scarcely perceptible) earthquake began, and has watched the marking pointer draw circles, loops, figures of 8, and numberless other curves. It appears, in fact, that the tangled character of the movements, which is strikingly shown in Plate XX, is by no means confined to such considerable shocks as the one there recorded, but is, in general, equally present in the most feeble disturbances of which records have been obtained.

In the earthquake of § 60 the principal movements consist of wide loops, nearly as broad as they are long. If we were to ascribe these to the simultaneous arrival of two systems of rectilinear vibrations, we should have to conclude that the principal movements in both systems reached the observing station together —a thing in the highest degree improbable. Taken in conjunction with the small amount of vertical movement, these (and similar features in other records) appear to admit of but one rational explanation,—that they are transverse waves whose direction of emergence is not very far from vertical.

CHAPTER VI.

MISCELLANEOUS INSTRUMENTS.

§ 63. *Fluid Pendulums.*

In Mallet's "Fourth Report on the Facts and Theory of Earthquake Phenomena"* an account will be found of a number of early seismometers, most of which may be classed either as solid pendulums or as fluid pendulums. To the first class belong the simple pendulum and the inverted pendulum of Forbes, to which allusion has already been made (§ 43). Under the second head we may include all arrangements in which a mass of fluid is caused to oscillate relatively to the earth by the earth's movements. These last are not well adapted to the absolute measurement of earthquakes, and are mentioned here chiefly for the sake of showing their inability to act as anything more than seismoscopes. Like most other early seismometers, they seem to have been based on the idea that an earthquake consists essentially of a single sudden impulse.

(1). Probably the oldest of these is that of Cacciatore, described thus by Mallet:—"It consists of a wooden circular dish about 10 in. diameter, placed horizontally and filled with mercury to the brim-level of eight notches that face the cardinal points and the bisecting rhumbs between, and are cut down through the lip of the dish, equally in width and depth all round. Beneath each such notch a small cup is placed, to receive such mercury as may be thrown out of each notch by an oscillatory displacement of the main mass of mercury, due to a general oscillation of the whole system. Either the volume or the weight of mercury found in each cup is supposed to measure the value of the displacement, and hence of the shock in its direction in azimuth." (2). Another, suggested by Babbage, is a bowl of molasses or other viscous liquid. (3). Another (Mallet) is a cylindric tub with chalked or whitewashed sides, partially filled with liquid, which is coloured so that it may show the height to which it is washed up during the disturbance. (4). An improvement on any of these is a set of U-shaped tubes, placed in different azimuths, and partially filled with mercury (Palmieri and Mallet).

All these are liable to the objection already urged against a common short pendulum,—that of having too great stability. This makes the amount of their movements depend so greatly on the agreement or non-agreement of the liquid's period of oscillation with that of the earthquake as to deprive these of all value, even as indications of the relative intensity of different shocks. If we avoid accumulated oscillation by using a viscous liquid, (2), we introduce a friction error of great but, generally, very unequal amount in different cases. The

* British Association Report for 1858, p. 72 *et seq.*

futility of seismometers of the kind now under notice will be readily seen by anyone who will take the trouble to imagine the motions which the liquid in a bowl would undergo during any one of the complex disturbances which have been described in the last chapter. From a knowledge of the height to which the liquid had been washed up at all points round the inner rim it would be impossible to determine anything definite as to the amplitude, direction, period, or duration of the disturbance.

U-tubes (4), which (provided with indices to show the displacement of the mercury in each) form an important part of Palmieri's seismic apparatus (§ 69, below), are equivalent as regards period to simple pendulums of half the whole length of the oscillating column, if we neglect friction and suppose the bore to be constant. A U-tube used as a seismometer differs, however, from a simple pendulum in this important particular, that it is the inertia of the liquid contained in the central or horizontal portion only that tends to keep the mass at rest when the ground moves horizontally. Apart therefore from the oscillations caused by its stability, the fluid does not behave as a steady mass. If, supposing the bore constant, we call M_1 the mass of fluid in the horizontal limb, and M_2 the mass of fluid in the two vertical limbs taken together, then when an acceleration a of the ground (to which the tube is fixed) takes place, the resistance to acceleration is $a M_1$, but the mass to be moved is $M_1 + M_2$. The fluid will therefore suffer an acceleration in the same direction as a and equal to $\frac{a M_2}{M_1 + M_2}$.*

The U-tube seismometer might be rendered not altogether unsuitable for absolute measurement by making it nearly straight, in the form either of an arc of large radius, or of a V with an angle of nearly 180° between the legs, or of a straight line with both its ends bent up at a very small angle. In that case, sensibly the whole of the mercury in it would act effectively in giving inertia; and, further, the equilibrium of the fluid might be much more nearly neutral than is practicable with the U form. The period of free oscillation of the fluid would then be $2\pi\sqrt{\frac{l}{2g\sin\theta}}$, θ being the inclination, to the horizon, of the tube at the ends of the liquid column.

§ 64. *Standing Columns.*

A simple form of rough seismometer recommended by Mallet† is a group of columns with plane bases normal to their lengths, which are set on a hori-

* Mallet (*loc. cit.* p. 81) falls into the same error as the Spanish writer referred to in § 50, when he says that the movement of the mercury in Palmieri's instrument "depends *wholly* upon the U-tube being *canted over* more or less in its own plane, so as to throw the legs of the tube out of plumb." Probably in no case is there any sensible action of this kind: the movement, of course, depends almost wholly on the inertia of the liquid. Even in a considerable earthquake the vertical motion is less than 1 mm., while the wave-length is generally some hundreds of metres,—the slope is therefore quite insensible.

† *Loc. cit.*, also Admiralty Manual of Scientific Enquiry.

zontal surface attached to the earth. The ratio of height to width differs in the columns forming the group, and any given earthquake is expected to throw over certain of them and leave those with broader bases standing. Sand is scattered round the base to prevent the overthrown columns from rolling, and the position in which they are found is expected to show the direction of the impulse (that is, if the base is circular). Mallet gives a formula for determining the maximum velocity of earth movement from a knowledge of the height and diameter of the most stable column which has been overthrown. But the formula involves the assumption that the motion of the base begins suddenly and continues, with uniform velocity, until the column falls; or else, that having reached its maximum value without disturbing the column, the motion suddenly ceases. Either of these assumptions, it need scarcely be said, is wholly inapplicable to the case of an earthquake. It would be very difficult to predict the behaviour of a standing column of given dimensions, if subjected to even the simplest of the disturbances described in the last chapter; and it would be obviously impossible to derive any definite knowledge of the character and amount and even the direction of the motion from a knowledge of whether, and how, the column had fallen. As a matter of fact, columns require to be very sensitive in order to be overthrown by even the sharpest shocks ordinarily experienced in Japan. Mr. Milne* has given an interesting account of attempts to observe earthquakes by their use. A column whose length was 10 times its diameter did not fall in any earthquake during a year of use; and even when the columns were so long as to require a very steady hand to set them up, they allowed many earthquakes to pass unrecorded. Mr. Milne adds: "Unless I had practical experience with these columns it would have seemed to me incredible that the smaller of them could possibly have remained standing." He suggests the use, in place of cylinders, of columns shaped like an inverted bottle or a truncated cone. His observations showed that columns of different sensibility sometimes fell in different directions, apparently showing that the more stable had their plane of rocking changed before they fell. With sensitive columns, especially, it is difficult to attain such perfect symmetry in all azimuths that a column will not fall more readily in some directions than in others.

Mr Milne has also tried the plan of propping up small columns (such as ordinary domestic pins or thin strips of glass) in a position as close as possible to the vertical, leaving them free to fall, in an earthquake, away from the prop. The results were not satisfactory.

§ 65. *Mallet's Ball Seismometer.*

In the "Report" already referred to, Mallet gives a long description of an instrument intended to act as a seismometer, in which balls are held in L-shaped supports, which are fixed to the ground so as to move horizontally with it.

* Trans. of the Seismological Society of Japan, Vol. III, p. 46.

Four balls are used, facing the four cardinal points. When any one of the balls is projected by an earthquake out of its L-support, it runs up an inclined plane and then falls back again, and the interval between its leaving and returning to the support is registered by means of a galvanic chronograph. The expectation was, that the first arrival of a shock would displace the ball facing the origin of disturbance, and hence, by breaking an electric contact, would register the instant of arrival. Then the ball facing in the opposite direction would be carried forward by its L-support, and so acquire a velocity equal to the maximum velocity of a surface particle. When this maximum was passed, it would leave its support and run up and back again along the inclined plane facing it. The interval of its absence from its support would be a function of the velocity of displacement, in calculating which the author ignores those movements of the support which take place during the interval in question. The supports for the balls are fixed to a platform held up by a spiral spring, whose compression was intended to give some information as to the vertical component.

A simpler form consists of two pairs of balls set, in L-shaped supports, on the tops of pillars, round the base of which damp sand is placed. The velocity of projection of any ball is given by the horizontal distance from the foot of the pillar to the point where it falls.

Apart from the errors which these methods of determination involve, a knowledge of the maximum horizontal velocity of a particle on the earth's surface is not of great interest, and furnishes, of itself, a very incomplete account of the motion.

§ 66. *Pendulums intended to swing.*

Attempts were made (before the introduction of the absolute measuring instruments described in Chapters II and III) by Mr. Milne,* by Mr. Gray,† and also by the present writer, to determine roughly the period of an earthquake's vibrations by seeing what length a pendulum (or other body capable of oscillation) should have in order to be set into most violent motion by the disturbance. In the author's experiments a set of inverted pendulums were set up, consisting of lead balls stuck on the ends of upright wires of various lengths and diameters. Each was provided with a simple index, consisting of a thread which was attached to the top of the ball, and passed through a hole in a fixed plate above, on the surface of which it rested. The pendulum whose free period agreed most closely with that of the earthquake waves would show that it had been most violently disturbed by pulling its thread farthest through the hole. But the period of the waves is too irregular to make the observation of much value.

§ 67. *Perry and Ayrton's proposed Seismograph.*

A universal seismograph, whose action does not depend on the production of a steady or approximately steady point, has been proposed by Messrs. Perry and

* Trans. of the Seismological Society of Japan, Vol. III, p. 28.
† *Ibid.* p. 30.

Ayrton in a paper "On a neglected Principle that may be employed in Earthquake Measurements."* These writers conclude, as the result of a mathematical examination of the dynamics of a body attached to the earth by stiff springs when the earth oscillates periodically, that such a body has, in certain cases, motions relative to the earth, which represent in miniature the motions of the earth's surface itself. This result is obtained by making the springs so stiff that the free period of the body's vibration is much shorter than the period of the earthquake waves. By the introduction of friction it is possible to get an approximation to accuracy with less stiff springs; and this is always desirable when the earthquake vibrations are irregular. A proposed instrument is figured, in which a mass is supported within a fixed case by five strong spiral springs, and provided with three multiplying pointers, adapted to show three rectangular components of its motion relative to the case. The pointers are to record their displacements on a band of paper, drawn along by a clock which is set in motion by the earthquake.

It appears that this suggestion has never been carried into effect. To suspend a mass by springs which would render its period much less than that of ordinary earthquake waves, and yet without practically preventing all motion, would be a matter of great difficulty; and the sudden changes which take place in actual earthquake motions would be a serious obstacle to the intelligibility of the records. Compared with the steady-point instruments of Chapters II, III, and IV, this one presents many drawbacks, and few, if any, advantages; and it is not remarkable that the principle on which it is based should, even after attention was directed to it, have remained neglected.

§ 68. *Electric Seismoscopes.*

A simple method of detecting the existence of small earthquakes, which has been very successfully used by Prof. Palmieri, consists in arranging oscillating pieces, such as short pendulums, in such a manner that a slight disturbance will cause them to make an electric contact. The current so established may be used to work a magnetic indicator, to stop or start or take time from a clock, to start a record-receiving plate, or, in other ways, to register the occurrence of the earthquake and serve useful purposes in connection with its measurement. For the detection of horizontal motion, Palmieri uses a simple pendulum, a few decimetres long, to the bottom of whose bob a platinum wire is fixed which stands over and dips into a hole or depression in a cup of mercury placed beneath it. To make a hole in the mercury, an iron pin is fixed in the centre of the cup, and the mercury is poured in so that its level is somewhat higher than the top of the pin, but not so high as to make the liquid meet over the pin. The pendulum hangs by a fine wire, forming part of the circuit; and the circuit is closed when, by any shaking of the ground, the wire fixed to the under side of the pendulum bob makes contact with the edge of the depression in the mercury.

* Phil. Mag., July 1879, p. 30; or Trans. of the Asiatic Society of Japan, Vol. V, p. 181.

For vertical movement, the pendulum bob is hung by a spiral spring just above a continuous surface of mercury in a cup below, so that any vertical vibration makes contact. Another form is a horizontal flat spring with a loaded end, and a point on its under side which stands just clear of a mercury surface.

A convenient form of the horizontal-motion apparatus is shown in sectional elevation and plan in figs. 38 and 39, Plate XXI. The pendulum *a*, consisting of a fine wire and a lead bob with a platinum point below, is hung from the top of the glass case *b*. The mercury is held in an iron cup *c* (shown in section), the height of which is adjustable by the screw *d*. One of the terminals *e e* is in electrical contact with the pendulum, the other with the cup of mercury. The arrangement of connections preferred by the present writer is shown in fig. 40. *A* is the battery consisting of a single large "gravity" Daniell's cell. It is kept always in circuit with the electromagnet *B*, whose resistance is considerable. When the seismoscope *C* acts the magnet is short-circuited, and its armature is thereby released. The release of the armature can be used to effect registration, start a record receiver, etc.

This arrangement may appear less simple than to put the seismoscope into a single circuit with the magnet and battery, the circuit being then normally open, but closed by an earthquake. The closed-circuit plan has, however, several advantages; amongst which perhaps the most important is this, that any failure of the battery is at once detected by the release of the armature. Any number of circuit-closing seismoscopes may, of course, be arranged as shunts to the same electromagnet, so that the armature will be released if any one of them acts during an earthquake.

To render Palmieri's circuit-closer additionally sensitive, Mr. Milne has added a multiplying arrangement, which is shown in fig. 41, Plate XXI.* Any deflection of the pendulum produces a magnified displacement of the lower end of the lever *l*, which then makes contact with the mercury in the cup *m*.

§ 69. *Palmieri's Seismic Apparatus.* †

An apparatus designed by Prof. Palmieri for the registration of small earthquakes was placed by him in the observatory on Vesuvius in 1856, and has been for some years in regular use in Japan. It consists chiefly of several circuit-closing seismoscopes, with a clock to register the times of and intervals between disturbances, and a group of U-tubes in different azimuths, which are provided with indices to record the displacement of the mercury and also with circuit-closing contacts. The circuit-closers are arranged in two groups, for horizontal and vertical motion respectively. These are connected to two electromagnets whose armatures carry a red and black pencil respectively, to mark the occurrence of horizontal and vertical earthquake motions on a band of paper pulled along below them by clockwork. This clockwork is started by whichever of the

* Trans. of the Seismological Society of Japan, Vol. IV, p. 98.

† Sismographes Électro-magnétiques de Louis Palmieri, Naples, 1878.

electromagnets is first affected, and simultaneously another clock is stopped. The band of paper then continues to run for 48 hours at the rate of 1 mm. per second, and so serves to receive notices of the occurrence of other disturbances after the first. The time of the first contact is given by the clock which stops; and the interval between that and subsequent contacts is determined by the length of paper unrolled from the first to subsequent marks. An alternative arrangement for receiving the marks caused by the attraction of the armatures consists of a clock with a projecting arbor which carries three drums, one of which rotates in 24 h., another in 1 h., and the third in 300 seconds. One of the armatures carries three pencils which write on the three drums, and the other carries one pencil which writes on the last drum only.

For the reasons which have been already sufficiently indicated, it cannot be said that Palmieri's apparatus can be trusted to measure even the relative "intensity" of different earthquakes. As a recording seismoscope it acts admirably, registering many slight earthquakes which would fail to affect a less sensitive instrument.

§ 70. *Time-takers.*

Besides the apparatus of Palmieri, many arrangements have been contrived by other observers with the view of determining the time of occurrence of an earthquake. Most of these act by stopping a clock, either by an electromagnet in conjunction with a circuit-closing seismoscope, or by direct mechanical action, as when a delicately supported mass is overthrown by the disturbance. A time-taker used by Mr. Milne has the advantage over any of these, that it records the time without stopping the clock. The apparatus is shown in fig. 42, Plate XXI.* *C* is a clock with a central seconds hand. The hour, minute, and seconds hands (*h*, *m*, and *s*) stand forward from the face; their extremities are bent outwards and are tipped with pieces of cork smeared with oily ink. A light wooden ring *R*, covered, on the side facing the clock, with a varnished paper dial which is graduated to correspond with the divisions of the clock face, is carried by a truck on wheels, which can run forward and make the dial on *R* touch the clock hands. This happen at the time of an earthquake, when the electromagnet *M*, which is in circuit with an electric seismoscope, allows the wheel *P* to be released, and to be carried round through half a revolution by the weight *W*. The rotation of *P* causes the dial to be advanced and withdrawn, by means of the connecting-rod *K*. The clock is not sensibly affected by the contact, which leaves marks on the dial *R* showing the position of the hands when it occurred.

From the account of earthquake motion given in Chapter V, it will be obvious that the time recorded by this or any other time-taking instrument will depend very largely on the delicacy of the seismoscope in connection with it. Earthquake motions generally begin so feebly as to make the time of their occur-

* Trans. of the Seismological Society of Japan, Vol. IV, p. 89.

rence, registered in this way, an exceedingly indefinite quantity. A valuable addition to any time-taker is a contrivance by which the instant when time is taken shall be marked on the continuously revolving plate of a recording seismometer. We can then see, by examining the record, how long the earthquake has been going on before the time-taking seismoscope acts, and obtain a much more definite notion of the connection between the instant of time registered by the clock and the principal motions in the disturbance.

§ 71. *Rossi's Seismoscope and Microseismic Apparatus.**

In Rossi's registering seismoscope, a seconds pendulum with a heavy bob is hung from a rigid frame, with freedom to swing in any azimuth. The bob is tied by four silk threads to four uprights which support the pendulum. The threads are made somewhat loose, and carry at the middle point of each a metallic needle, whose weight causes the branches of the thread to make a very obtuse angle with each other. Each needle stands just over a cup of mercury, with which it makes contact when the pendulum swings, or rather when the frame moves relatively to the bob. The vertical motion of the needle is $\frac{1}{2}\tan\frac{\theta}{2}$ times the horizontal motion of the ground (in the plane of the thread), θ being the angle formed by the two halves of the thread at the needle. Fig. 43, Plate XXI, gives a sketch of this ingenious method of multiplying the motion of a pendulum. There *a* is the bob: the point of suspension is carried by four posts, a part of one of which appears at *b*. *cc* is one of the four silk threads; *d* the corresponding needle, which is partially supported by the delicate spiral spring *e*; and *f* is the cup of mercury. The four cups are arranged to close four separate circuits, each being provided with an electromagnet and pencil, which records the closure of the circuit on a strip of paper drawn by clockwork. Besides acting as a seismoscope, the apparatus therefore shows the quadrant towards which the pendulum moves each time contact occurs.

In the microseismoscope there are five pendulums of different lengths—one in the centre and four round it. Each of the latter is tied to the central pendulum by a bent silk thread, which (as the former apparatus) causes a needle to make contact with a cup of mercury whenever a relative displacement of the connected bobs takes place. The pendulums have different periods of oscillation, and are therefore likely to acquire different amounts of swinging motion during any disturbance. The apparatus has been successfully used in Italy to detect very minute earthquakes since 1876.

§ 72. *Other Microseismoscopes.*

Rossi* in Italy and Milne† in Japan have used microphones to detect minute disturbances of the ground. Another way of detecting the feeblest earth tremors, if we know when to look for them, is to observe the image of a

* Telegraphic Journal, Vol IX, p. 460.
† Trans. of the Seismological Society of Japan, Vol. III, p. 37.

fixed object, such as a star, in a basin of mercury. This plan was used by Mallet in experiments on the speed of transit of artificial earthquake waves through sand and rock (Brit. Assoc. Report for 1851). The following description of a registering seismoscope, capable of considerable sensibility, but somewhat liable to give false indications, is given by Milne*:—"If a light, small sensitive compass needle be placed on a table, it will be found that a small piece of iron like a nail may be pushed so near to it that the needle assumes a position of extremely unstable equilibrium. If the table now receives the slightest tap or shake this condition is overcome, and the needle flies to the iron and there remains. By making the support of the needle and the iron the poles of an electric circuit it would be possible to register the time at which motion took place with considerable accuracy."

§ 73. *Optical method of multiplying the displacement of a pendulum.*

In the experiments referred to in the Introduction, Messrs. G. and H. Darwin employed a very delicate means of measuring changes in the position of a pendulum bob, which may also be employed in the measurement of very minute earthquakes. The method was to hang a light mirror by two fibres, one attached to the bob and the other to an adjacent fixed support. When the bob moved the plane of the mirror was changed, and the amount of change was read either by reflecting a beam of light from a lamp upon a scale, or by observing the scale reading reflected from the mirror into a telescope. The experiments of Messrs. Darwin had for their object the detection of slow changes in the direction of the vertical, and for this reason they eliminated sudden tremors by hanging the pendulum in a liquid. In the microseismic application of the same method, the pendulum and mirror should be left as free as possible to respond to sudden tremors of the ground; but slow displacements are to be altogether discarded. Mr. Milne† has attempted by a similar method to register minute motions of the soil. His pendulum bob was kept in contact with the ends of two wires laid in fixed guiding pieces of glass tube, and placed at right angles to each other. The other ends of the wires abutted against two mirrors, so as to turn them round if the bob should become displaced. Some movement was found to have occurred almost every time the instrument was examined; but it is impossible to tell how much of this was caused by earth tremors, how much by changes in the vertical, and how much by movements of the pendulum's supporting point, due to moisture, unequal heating, and other causes. To arrange the apparatus in a manner which would eliminate all sources of error due to this last head would be scarcely possible; and if, by continuous observation, actual tremors were distinguished, it would still be a matter of great difficulty to separate out those due to such obvious causes as neighbouring vehicles and pedestrians from the natural disturbances which it is the object of the apparatus to detect.

* *Loc. cit.*, p. 37.
† *Ibid.*, p. 30.

§ 74. *Measurement of earthquakes by reference to their Effects on Buildings.*

Attempts have been made to infer the character of earthquake motions from the traces which destructive shocks leave behind them, in fractured walls, projected fragments, overturned columns, etc. The two large volumes in which Mallet has described the great Neapolitan earthquake of 1857* are in great part filled with calculations of this kind. So far as these refer to the direction of the principal movement (on the supposition that there was a principal movement with a definite direction), they are not without value; but in applying his measurements of projection and overthrow to the determination of the greatest velocity of displacement, Mallet has throughout made an assumption which entirely vitiates his results. The assumption, already alluded to in speaking of standing columns (§ 64), is that the body which suffers overthrow does so in consequence of a sudden change of momentum with respect to the ground, and that the momentum so acquired is left free to do its work, in causing the body to fall, without further interference. In other words, it is assumed either that the motion of the ground begins quite suddenly, and then continues (until the body falls) with a uniform velocity—the velocity which is calculated by Mallet's formulas; or else that, having communicated this velocity to the body, the ground suddenly stops, and stays at rest until the body falls. It need scarcely be pointed out, after the results given in Chapter V, how wide of the facts this assumption is. And it is difficult to see how any observations of bodies projected or overthrown can be of the smallest use as data from which to determine earthquake motions, when these have the extraordinary complexity which absolute measurements have shown them to possess in Japan.

Mallet's treatment of fractured structures is even more unsatisfactory, and, indeed, involves a distinct error. Taking the case of a column which is fractured at a horizontal plane through the base by a horizontal impulse, he equates the momentum multiplied by the height of the centre of gravity, with the moment of resistance of the section to rupture. It is, however, the greatest rate of acceleration, and not the greatest velocity, which determines whether fracture shall take place. If we assume the column to break without sensible bending, so that the act of rupture (which is to be clearly distinguished from the overthrow which may or may not follow it) occurs with sensible instantaneousness, we should equate the moment of the resistance to acceleration with the moment of resistance to rupture. Calling M the mass above the fractured section, a the acceleration, h the height of the centre of gravity above the section, I the moment of inertia of the section about a horizontal central axis perpendicular to the direction of acceleration, b the shortest perpendicular distance of this axis from the edge of the section, and f the modulus of rupture, we have

$$Mah = \frac{fI}{b}, \qquad \text{or} \qquad a = \frac{fI}{Mbh}.$$

* The First Principles of Observational Seismology, London, 1862.

CHAPTER VII.

SUMMARY AND COMPARISON OF INSTRUMENTS AND METHODS.

§ 75. *Uselessness of all except Steady-point Seismometers.*

Enough has been said to show that, of all actual seismometers, those only are of value which aim at giving a steady line or a steady point during the disturbance—a steady line with respect to motion in one direction, or a steady point with respect to motion in two directions, or in all. Cruder devices, such as standing columns, fail because of the complexity of earthquake motion. They cannot be trusted to yield even relative measurements of amplitude or of destructive power; and as to direction, it is impossible to speak of the direction of the ground's motion when we find displacements of nearly equal value occurring in all possible azimuths, during the continuance of a single earthquake.

§ 76. *Classification of Steady-point Seismometers.*

We may classify these instruments with respect to the component or components of motion they are designed to measure, as follows:—

I. Those possessing one degree of horizontal freedom, and therefore capable of measuring one component of the earth's horizontal motion. They are to be used in pairs, giving two components, which are most conveniently taken at right angles to each other. To this class belong the horizontal pendulum in its various forms (§§ 23-28); the common vertical pendulum (or any of the modifications of it given in Chapter III) when suspended, like the pendulum of a clock, on an axis, not on a point; the rolling cylinder (§ 34), with or without a heavy slab. A sphere rolling in a fixed V-groove might be added to the list, also a flattened-out U-tube filled with mercury (§ 63).

II. Instruments possessing two degrees of horizontal freedom. This class includes the common pendulum and its modifications (the duplex pendulum etc.) when suspended by a point (§§ 35 *et seq.*); the horizontal pendulum with jointed supporting frame (§ 29); the rolling sphere, or spheres carrying a slab (§§ 31-33); a system of rolling cylinders at right angles to each other, with a slab between (§ 34).

III. Instruments possessing vertical freedom only. The loaded horizontal bar with flexible or extensible support, and its modifications (§§ 45-48). It would not be difficult, were it at all desirable, to design instruments which would form two more classes, namely IV, instruments possessing vertical and also one degree of horizontal freedom; and V, universal seismometers, having three degrees of freedom.

§ 77. *General principle of Steady-point Seismometers.*

The steady line or steady point is obtained by pivotting a mass, or group of masses, with appropriate freedom, and in nearly neutral equilibrium. The axis about which the body or system spontaneously rotates in consequence of the component of earth-displacement it is designed to measure, furnishes an approximate standard of rest.

It is only approximate; first, because the earth's motions are not indefinitely small; second, because the stability of the system causes some motion to ensue after every displacement; and third, because of friction at the joints and at the index which is used to record the earth's displacement with respect to the axis of spontaneous rotation. The first error may be rendered inappreciable by placing the axis of spontaneous rotation sufficiently far from the supports, compared with the extent of motion to be measured. The degree to which we may reduce the second and third sources of error depends on the method adopted for registering the motions.

§ 78. *Methods of registering the movements of the ground relative to the Steady Point.*

These are four in number:—

[1.] By an index which shows the greatest amplitude of relative displacement, without showing its direction.

[2.] By indices which show separately the greatest displacements in two or more directions.

[3.] By a writing pointer which draws a diagram of the motion on a fixed plate.

[4.] By writing pointers which show the successive motions, or components of them, in conjunction with the time, on a plate or drum which is kept always moving uniformly.

[5.] By pointers writing on a plate or drum which moves uniformly after being started into motion by the earthquake itself, but is normally at rest.

In applying method [4] or [5] to a double-freedom instrument (of Class II), we may use either a single pointer to record the earth's complete horizontal motions on the moving plate, or two pointers arranged so that each records only one component. Plate VIII shows both plans, applied to a long pendulum seismometer.

§ 79. *Objections to Static Records.*

The static records which are obtained by methods [1], [2], and [3] give, of course, less complete information than [4] and [5], inasmuch as they do not show the relation of displacement to time. The results obtained by method [3] are of much greater interest than those which [1] and [2] can yield. But

besides possessing the defect just mentioned, all static records are open to another important objection. If the equilibrium of a seismometer is very nearly neutral, the so-called steady-point is liable to become shifted during an earthquake to a considerable distance from its initial position; and even during intervals of rest, especially when these are long, a gradual creeping of the pointer occurs, due to slight accidental displacements of the line or point of support, through changes of temperature, warping, and other causes. Hence to use [1] or [2] we must make the equilibrium tolerably stable. Another difficulty then presents itself, namely the tendency which a stably hung body has to acquire, during a long series of shakes, an oscillation whose amplitude may be comparable to or even much greater than the motions of the point of support. Only one way remains by which this objection may be overcome: the tendency to oscillate may be removed by introducing a considerable frictional resistance (§ 39). This, again, gives rise to error by making the recorded displacements too small, especially in slight earthquakes. It is, however, the only method by which records obtained by plans [1] and [2] can be prevented from being absolutely meaningless. In [3] the case is somewhat different. There the creeping of the steady point, which occurs when the equilibrium is nearly neutral, is not so fatal an objection as it is in [1] and [2]; for it is often possible in the record to distinguish, more or less completely, any motion of this kind, especially when the principal earthquake motions are decidedly not rectilinear. The diagram in the centre of Plate XIX may be referred to as an example of a static record which has not been rendered unintelligible by the nearly astatic character of the seismograph which gave it.

§ 80. *Records of displacement in conjunction with time.*

Records which show each successive displacement in conjunction with the time are far more valuable than static records, both on account of the greater fulness of the information they yield, and because they avoid to a great extent the sources of doubtfulness or error to which static methods of recording are liable. When the movements are recorded on a continuously moving plate, the equilibrium may safely be made much more nearly neutral than is practicable with a statically recording instrument; and the friction, instead of being artificially increased, may advantageously be reduced almost without limit. Any moderate degree of progressive displacement of the so-called steady point, by the accumulated effect of successive earth waves, leads to no serious confusion; and any long-period swinging that may occur is easily distinguished from the legitimate portions of the record. A small amount of stability must be given to prevent the former effect from becoming excessive; but the equilibrium may be so nearly neutral that the slight friction which, in the most favourable conditions, the pivots and the marking pointer must produce, will suffice to make immoderate swinging impossible. When registering on a continuously moving plate, a well constructed and well adjusted seismograph should make one complete

oscillation in about 5 seconds, and its decrement of amplitude should not exceed about 1 mm. per oscillation.

When the record is deposited on a plate or drum started by the earthquake and stopped soon after it, the equilibrium may properly be made still less stable than this; for in that case "creeping" of the pointer before or after the disturbance does no harm.

Methods [4] and [5] have each certain merits and defects. Experience shows that when method [4] is used, and the equilibrium is nearly neutral, the pointers creep about through small distances almost continually, from causes probably the same as those which prevented the mirror in Messrs. Darwin's experiments (referred to in the Introduction) from remaining at rest. The result is that the circles which the pointers trace out on account of the continuous rotation of the plate become gradually widened; and hence when an earthquake occurs its smaller movements are indistinctly recorded, and its beginning is sometimes untraceable. Instances of this will be seen in several of the Plates. The position of the pointers on the glass plate, and the plate itself, require to be changed from time to time, when the lines become too wide. On the other hand, method [5] may allow a part of the earthquake to pass unrecorded; and it is open to the further objection that there is no easy way of seeing that the starting gear is in good order, whereas the apparatus used in method [4] shows at a glance whether it is in a fit state to receive a record. As regards difficulty and cost of construction, [4] requires a much more carefully made and costly piece of clockwork, but avoids the circuit-closer, magnet, and battery which must be combined with the simpler clock of method [5]. For use in an observatory where the instruments can receive frequent inspection and skilled attention (a condition essential to success in all seismic observation), the writer greatly prefers method [4].

Where the normal position of the index depends upon the pull exerted by a spring, as in the vertical seismometers of §§ 46 and 47, the creeping tendency alluded to above is so great as to make [5] the only practicable method of registration.

§ 81. *Constructive details.*

The principal points to be attended to in the design of an absolute seismometer are these:

The point or axis of support (points or axes, if there be a group of masses instead of only one) must partake as exactly as possible of the motion of the earth at the place of observation. This requires a rigid post or stone table (whose dimensions must be greatly less than the shortest wave-lengths in the earthquakes to be measured), firmly imbedded in the earth; a steady clamp, giving definite points of attachment (§ 23); and a rigid supporting frame to carry the point or axis of support.

The distance from the axis of support to the steady line must greatly exceed the greatest earth-motion to be measured, except where the apparatus is astatic,

or nearly so, for large as well as for small displacements, and there is no sensible rotation of the steady line, during displacement, about the axis of support.

The moment of frictional resistance, due to the pivots and pointer, must be very small relatively to the moment of the effective inertia.

The displacement of the multiplying pointer, in the plane of the surface on which it writes, must be a constant multiple of the displacement of the ground with respect to the steady line. The pointer must, however, have freedom to move, through a small distance at least, at right angles to the surface on which it writes. To give it this freedom the writer has, after several trials, found no plan so satisfactory as the use of a transverse joint, examples of which will be found in all his seismographs.

The record-receiving plate or drum must have its axis of rotation definitely attached to the earth, or, preferably, to a piece which is rigidly connected with the axis of support of the seismometer whose displacement it is to record; and the motion of the record-receiver must be steady and continuous during an earthquake. These conditions are fulfilled in the writer's apparatus by the independent supporting frame which is used to carry the glass plate, without shake; the rolling-contact gearing, in place of toothed wheels, which, unless made with extreme accuracy, would give unsteadiness to the motion; and the governor, whose action is not sensibly spasmodic, and which is designed with a special view to its being undisturbed by the motion of the ground. To fix the smoked-glass plate directly to a slow-running arbor of the clock, though apparently a simpler method of support, gives more chance of irregular motion, and a considerable likelihood that the plate may shake.

A glass surface is preferable to paper for the reception of records, on account of its smoothness; and a plate is in many ways more convenient than a drum.*

* To obtain permanent copies of a record traced on a smoked-glass plate, the plate is first to be coated with photographer's varnish, by pouring the liquid on it, and gently sloping it to allow the varnish to spread uniformly. After it is dry, the "blue process" of taking photographs may be applied as follows. –

Dissolve one part of Ammonio-Citrate of Iron in eight parts of water, and make a separate solution containing one part of Ferricyanide of Potassium also dissolved in eight parts of water. Immediately before taking the photographs mix four parts of the former solution with three parts of the latter. Spread the mixture evenly over a sheet of paper (either with a glass rod or with a flat brush) and hang the paper up to dry in a dark room. When dry, expose it under the glass plate, with the varnished side next to the paper, care being taken to bring the paper and the plate into immediate contact. This is most easily done by laying the sensitized paper on a thick cushion consisting of several layers of cloth, and then pressing the glass plate firmly against it by means of a second sheet of plate-glass which may be held down by clamps. In sunshine the exposure should last from eight to twenty minutes.

After exposure, the paper is to be dipped into a tank of water and allowed to soak there for about ten minutes. It must be thoroughly washed, so that every part of the unaffected chemicals on the paper may be removed. It may be then dried in the open air.

The solution of Ammonio-Citrate of Iron should be kept in a dark place; and it is best to prepare it not long before use. The sensitized paper may be prepared in large quantities and laid by in a dark drawer; but if it is kept long the photographs are not so clear as those obtained by the use of freshly prepared paper.

When the plate is to be set in motion by an earthquake, a light driving clock is desirable, whose speed will quickly attain its steady value. The same form of governor as is used in the continuously running clock may appropriately be applied, and the same means of communicating motion to the plate.

Figs. 44 and 45, Plate XXI, give a section and plan of a driving clock which is started by the release of the armature in fig. 40. The cord *a* passes over a pulley on the ceiling, and carries a driving weight of about half a kilo. *b* is a drum on which the cord is wound: its arbor projects on both sides and is jointed, as in fig. 8, Plate III, to two spindles which revolve in slot-guides *cc* and carry discs *dd*, which roll on two glass plates near their edges, and so cause them to revolve. These form two record-receivers; and a third is also driven by the same clock, by means of an independent cord on *b*, which, when the clock runs, drags along a carriage on a straight pair of rails, the carriage having a long strip of smoked glass fixed to it. The axles and wheels of the carriage, and the rails, are arranged on strict kinematical principles, to avoid the possibility of any transverse shaking; and the cord which drags the carriage is kept tight enough to prevent longitudinal shaking.

§ 82. *Requirements of a Seismological Observatory.*

For the registration of ordinary earthquakes the equipment, to be fairly complete, should comprise:—

[A]. A pair of single-freedom horizontal seismographs writing on a plate which is kept always revolving.

[B]. A pair of single-freedom horizontal seismographs writing on a plate which is started into motion by an earthquake.

[C]. A double-freedom horizontal seismograph writing on a plate which may either be kept always revolving, or be started into motion by an earthquake.

[D]. A double-freedom horizontal seismograph writing on a fixed plate.

[E]. A vertical motion (single-freedom) seismograph writing on a plate which is started into motion by an earthquake.

[F]. For these one continuous-motion driving clock with a governor will be needed—like that shown in Plate II. It may drive two plates, if required, by having the arbor from which they take their motion prolonged outwards on both sides.

[G]. A second smaller clock, also with a governor, and with a magnetic starting appendage, will be required for [B] and [E].

[H]. One or, better, several circuit-closing seismoscopes (§§ 68 and 71) should be put in connection with this clock.

[I]. The same circuit-closer should actuate a time-taker, to give a general idea of the time of occurrence of the disturbance.

[J]. A useful addition is a set of electromagnetic time-tickers (in one circuit with a clock), which mark seconds simultaneously on all the

revolving plates. This apparatus is to be started by the same contact which starts the plates of [B] and [E] and actuates [I]; and it must be arranged to cease acting before one revolution of the plates is completed, else the marks will become unintelligible.

The use of [J] is to allow the contemporary parts of all the records (except those of [D]) to be readily identified, and to show at what part of the disturbance the time-taking appliance has acted. It also provides, on the plates, a scale of time which is convenient in determining the period, etc. of the waves.

For [A] it appears difficult to find any instrument superior to the horizontal pendulum with light pivotted frame and pivotted bob (§ 24). The construction shown in Plate II will be found very convenient; but the stand, there represented as made of wood, might with advantage be entirely of metal. This would probably prevent, in part, a tendency to "creep" which the pointers are found to possess. The instrument has the advantage of great compactness, facility of transport, and an almost entire freedom from liability to get out of adjustment, or out of order in any way.

[B] is desirable as a supplement to [A] in order that we may have a record which is not obscured by the somewhat broad datum-line formed when [A] runs for some time, either before or after the earthquake.*. The driving-clock for [B] and [E] should of course be arranged to run for no more than a few minutes, so that the record may not be obliterated by "creeping" after the disturbance is over. [B] may suitably consist of a pair of horizontal pendulums with flexible joints at one or both of the two points which determine the axis of support of each (§ 27 or § 28). Their equilibrium may be more nearly neutral than that of [A], and their frictional resistance should be reduced to the lowest possible value.

[C] may conveniently consist of a long pendulum like that of Plate VIII. By placing a weight on the multiplying lever, near the top, we may approximate to the duplex pendulum of § 41, and in that case the length may be reduced. The record given when a double-freedom horizontal seismograph writes with one pointer on a revolving plate is not so completely intelligible as a pair of component records, each showing motion in one azimuth, for it merges the tangential part of the earthquake motion in the continuous motion of the plate itself; but the single-pointer plan has the merit of showing, at a glance, the kind of motion and the changes of direction which occur during the disturbance. These are, of course, deducible from two-component records, but only by a somewhat

* An instance of the usefulness of an apparatus of this kind was furnished by a recent very slight earthquake, the maximum amplitude of whose motions was so small that the wide datum-lines on two continuously running plates obscured, almost completely, the records traced on them. The disturbance, however, actuated an electric seismoscope and started a third plate, on which a very clear record was given by a pair of horizontal pendulums and by the vertical-motion seismograph of § 48. The greatest horizontal motion was about 0.3 mm., and the greatest vertical motion about 0.1 mm.

tedious process, which it is practically difficult to apply when the motion of the plate is slow and the period of the waves is short.*

The same steady point—namely, that of [C]—may be used to write a pair of two-component records: this is easily done when the effective inertia is great, as in the instrument of Plate VIII, where the arrangement in question is adopted (figs. 27 and 28).

For a static record, [D], the duplex pendulum will be found convenient. There is, however, no reason why we should not take a static record, as well as a record on a moving plate, from the same long pendulum as gives [C], provided its effective inertia is so great as to make the friction of an additional marking pointer scarcely noticeable. To do this a second transversely hinged pointer might project from the vertical multiplying lever in fig. 25, Plate VIII, and write on a fixed plate carried by a bracket above or alongside of the revolving plate.

A double-freedom instrument might be made for [C] or [D] by combining two single-freedom seismometers so that, instead of tracing separate records, their motions should be compounded by a separate marking lever, pivotted with freedom to move in any azimuth. It is scarcely likely, however, that this plan would have any advantage as compared with the use of a double-freedom instrument of the kind already described; and it would of course involve a greater number of parts. For [E] either of the horizontal bar instruments described in §§ 46-48 is suitable. The circuit-closers of Palmieri and Rossi appear perfectly satisfactory for [H]; and Mr. Milne's time-taker should serve well for [I].

The various seismographs may usefully be constructed with different ratios of multiplication, appropriate to earthquakes of various amplitudes. One, preferably [C], should be capable of a considerable range of movement, and should be provided with a supplementary pointer, writing without multiplication, to serve for the registration of unusually large shocks, whose amplitude is so great as to throw the ordinary indices out of gear.

§ 83. *Determination of the Direction and Velocity of Transit.*

The foregoing account of methods of earthquake measurement has referred entirely to the determination of the character of the motions at a single observing station. Another problem, of much interest, is the determination of the direction and velocity of propagation of the earthquake waves. The direction, especially, is important on account of the information it gives as to the position of the origin. If we know, rigorously, the time of arrival of an earth-wave at three stations on the surface, and assume its velocity and direction of propagation to be constant between them, an obvious geometrical solution gives the direction in azimuth

* To facilitate the process of compounding the principal motions recorded by a two-component instrument, the plate, before being withdrawn after an earthquake, should be turned round by hand, and held successively in a number of positions, while lines, like those in Plate XIX, are simultaneously drawn by displacing both pointers.

and the horizontal velocity of transit of the wave. Four sufficiently distant stations furnish data for determining the *epicentrum*, or surface-point vertically above the origin, the velocity being assumed constant and the wave-front spherical. A fifth station, on the same assumptions, if properly chosen, gives the additional information needful to determine the depth of the origin. Knowing the instants of arrival at five stations, we have five simultaneous equations for the three coordinates of the origin, the velocity, and the instant of disturbance at the origin.

But, in fact, even the first of these schemes, and still more the second and the third, is generally incapable of sufficiently exact application to an earthquake as a whole, on account of the ill defined beginning and long duration of the disturbance. By the time it reaches a station distant from the origin, the shock is very far from consisting of a single impulse whose time of arrival may be recorded with precision. A glance at any of the diagrams described in Chapter V will show how indefinite the time of arrival must be, whether we determine it by the sensations of an observer or by using a mechanical or electrical seismoscope. The beginnings of motion are usually so gradual that the time shown depends largely on the sensibility of the appliance used to detect disturbance; and in attempting to measure, by time-takers, the interval between the times of arrival of an earthquake, as a whole, at two or more stations, we are liable to errors of perhaps ten seconds or more—errors which may even exceed the quantities to be measured. It is true that by increasing the distance between the stations we make any given error relatively less important; but, on the other hand, the character of the complex system of waves will then be more likely to differ at different stations, and the errors of time measurement will thereby be increased. It is only in violent earthquakes, where stations may be taken at such distances from each other as to give intervals greatly exceeding the duration of the shaking at any one point, that trustworthy results can be obtained.

The same objection applies with equal force to the measurement of time-intervals by telegraphing automatically the time of arrival at several stations, and recording the signals on a chronograph.*

In a paper read before the Seismological Society in February 1881,† the present writer, after pointing out the impracticability of obtaining precise time-intervals by reference to an earthquake as a whole, gave a scheme by which the velocity and direction of transit might be determined provided we could identify, at three or more stations, any one motion out of the group constituting an earthquake. It was proposed to put up three (or four) pairs of continuously recording horizontal pendulum seismographs at three (or four) stations connected electrically

* Prof. W. S. Chaplin had designed and, in fact, prepared an apparatus to carry out this method, just before the writer obtained his earliest records of earthquake motions on a moving plate. The character which those records showed the motion to possess led Prof. Chaplin at once to abandon his project.

† Transactions, Vol. III, p. 111.

with each other. The plate at each station was to be moved by an independent clock of the usual kind, it being needless that the plates should run at the same speed. So far, the arrangement would give three (or four) pairs of independent records of any earthquake. To complete the scheme, time must be simultaneously marked on all the plates during the disturbance. At one station a seismoscope was to be placed, which, on the occurrence of an earthquake, would start, or throw into electrical connection with the station circuit, a clock which should send time signals every second to all the stations, to be recorded by electromagnetic pointers on all the plates. The signal-sending clock should stop, or be automatically cut out of the circuit, before the plates had accomplished quite one revolution from the beginning of the time signals.

The first signal, marked on all the plates, would serve to identify the same instant of time in all the records, and the subsequent signals would determine the velocity of the several plates. The scheme would work only if we could recognise the same earth-wave on all. It would then be easy to measure with much exactness the intervals between the instants at which the same phase of the same wave appeared at all the stations.

The method gives so precise a means of determining small intervals of time that we might use stations at no great distance from each other—say 500 metres, which would probably give intervals of about one or two seconds. These, however, would serve only to determine the azimuth of the *epicentrum*. For its position, four much more distant stations might perhaps be used; or, better, two independent groups of three near stations, the groups being at a considerable distance apart. Other plans might obviously be arranged by combining three stations near each other with one distant station or more—all electrically connected.

But the practicability of any of those plans depends on this fundamental condition, that some one wave in the disturbance is to be identified at all the stations. The writer's observations have shown (what, indeed, was to be anticipated) that different seismographs recording the same earthquake at the same station give closely accordant results. It remains to be seen how far the character of the motion will prove constant when observations are made at stations whose distances from each other are comparable to or much greater than the wave-lengths of the constituent vibrations. If the curved path in which a surface particle moves be due to the simultaneous passage of two or more systems of independent waves, travelling in different lines, no identification will be possible. But the large loops of Plate XX show that, at least in some cases, the principal displacements in two directions occur together—a thing very unlikely to happen if they are due to two independent systems of waves. There appears, therefore, a fair prospect that, in favourable cases, the identification of some one prominent motion at stations tolerably far apart may be possible; and in that case the writer's method will serve to determine the speed and direction of transit.

§ 84. *Velocity of Transit of Artificial Earthquakes.*

The method in question has been applied by Messrs. Milne and Gray to measure the speed of transit of artificial disturbances.* The bearing of the origin being known, two stations were of course sufficient, and at them horizontal pendulum seismographs were set. The soil was hardened mud. The velocities found were 438 feet per second for normal waves, and 357 feet per second for transverse waves.

The earlier experiments of Mallet† gave the following velocities:—

In sand	825 feet per second
In jointed granite	1306 „ „
In solid granite	1665 „ „

But from the known elasticity and density of solid rock, and from other observations, it is probable that the last named velocity is much too low; and that in a continuous mass of rock as high a velocity as 8000 or even 12000 feet per second may be attained.

§ 85. *Experimental Tests of Seismographs.*‡

To find experimentally the accuracy with which a seismograph registers motions of any assigned form and period, let the seismograph to be tested, with its receiving plate and driving clock, complete, be placed on a shaky table. Side by side with the multiplying lever of the instrument let a second lever be arranged, pivotted by an altogether independent fixed support, and connected to the table at one point, so as to give the same ratio of multiplication as the actual instrument. This lever is to be provided with a point which writes on the plate close by the marking point of the seismograph. If the table is now shaken, the component of earth-motion transverse to the levers is recorded by both pointers; and the agreement of the two records will show the accuracy of the seismograph. To make the test as conclusive as possible the table should be forced to move in such a manner as to give records resembling those which experience shows actual earthquakes give. For a vertical-motion seismometer the same plan may be followed, if we use, instead of a table, a spring board capable of vertical shaking.

In applying the test to a pair of horizontal pendulums with pivotted bobs, a convenient plan is to place the two pendulums parallel or facing each other and so that their marking points come on the same radius of the plate. Then let the bob of one be held fixed by means of a bracket from a neighbouring wall: this will ensure that its "steady line" is rigorously steady. The steadiness of the other is then tested by shaking the table, and seeing how closely accordant the two records are.

* Phil. Mag., Nov. 1881. Also Proc. Royal Society, Vol. XXXIII, p. 139. (Dec. 1881).

† British Assoc. Reports for 1851 and 1852.

‡ See also Proc. Royal Society, Vol. XXXI. p. 444.

Plate XXII gives a number of examples of this test, as applied to the horizontal pendulum of § 24. The curves marked *a a a* were given by the pointer whose bob was fixed: they represent the true displacements of the table, magnified 4 times. The curves *b b b* were given by the pointer whose bob was free. The general agreement of the two records with each other shows that the steady line of the free seismograph did in fact remain very nearly steady, during movements of much variety. The pointers were set facing each other, and so would have described arcs of opposite curvatures on a stationary plate—a fact which must be taken into account in comparing the records.

APPENDIX.

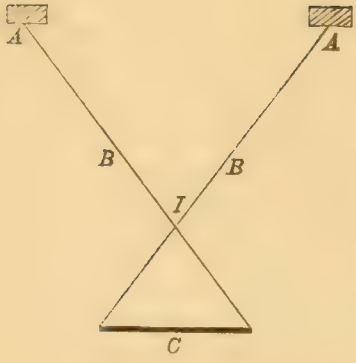
ASTATIC SUSPENSION BY LINKWORK.

At a meeting of the Seismological Society of Japan, held while this memoir has been passing through the press, Prof. C. D. West exhibited a model of a new method of astatic suspension, applicable to seismometry. A massive bar *a* (fig. 46, Plate XXIII) is hung by a system of links *bbcc*, like the so-called parallel motion of Watt, whose effect is to give the bar freedom to move in an approximately straight horizontal line, in the direction of its own length. A small degree of stability is secured by placing weights *dd* at the bottom of the links *bb*, or by making these slightly shorter than the lower links *cc*. To guard against motion at right angles to the plane of the links a guide-bar *ee* is added, which passes through holes in the upright supports. This, however, is liable to introduce an objectionable amount of friction during an earthquake; and, apart from it, the numerous joints can scarcely be prevented from causing more frictional resistance than is permissible in a good seismometer. The upper links, which are ties, may be made of flexible cord or wire instead being of jointed, but even then so many joints will remain as to constitute a serious defect.

More recently several methods of astatic suspension have occurred to the present writer, one of which, in particular, seems well adapted to the measurement of earthquake motions, especially when these are great.

It is obvious that the mass whose inertia is to give steadiness in a seismometer may be hung in neutral equilibrium by any system of links which produces an exactly or approximately straight-line motion, provided the links are placed so as to make this line of motion horizontal. We might, for example, suspend a mass by a pair of Peaucellier linkages, with freedom to move horizontally, and thereby obtain absolute astaticism throughout the whole range of its motion; or, by reducing the distance between the two pivot points in each linkage, we might compel the mass to move in an arc of very large radius, and thereby give it the slight stability needful in a seismometer. But this plan would be open to the same objection as the suspension by Watt's linkage proposed by Mr. West,—the multiplicity of joints would give rise to an intolerable amount of friction.

To avoid friction we should select a form of linkage with as few links as possible, and these all ties, in order that we may easily substitute flexible cords for rigid pieces with joints. No linkage satisfies these conditions better than the approximate straight-line motion of Tchebicheff, illustrated in the sketch. *AA* are fixed supports. *BB* are two equal links, which, when the apparatus takes this form, may be flexible cords. They cross each other and are connected to the end of a hanging bar *C*. The vertical distance of the middle of *C* from the line *AA* is equal to the distance *AA*, while the length of the hanging bar is



$\frac{1}{2}AA$. Then the middle point of the bar moves in a line which is very approximately straight and parallel to AA, provided its excursions lie within a range not greater than the distance between the fixed supports. These proportions will give sensible astaticism when AA is horizontal; but by making the depth of the hanging bar somewhat greater, or by placing the centre of gravity of the hanging bar below the line of its attachment to the links BB, we may give it any desired amount of stability.

When BB are single cords the system is azimuthally unstable, but it is easily prevented from rotating about a vertical axis by making each of the suspending links B double, in two parts which form a V whose vertex is at the end of C, and whose base is a line through A perpendicular to the plane of the paper. Further, this prevents oscillation perpendicular to the plane of the paper, and so leaves none but the desired freedom. To increase the steadiness we may add a mass which should be as much as possible concentrated at the centre of C. This may be pivotted about a horizontal axis perpendicular to C, through its centre, and in that case the mass is equivalent to a particle concentrated there. Figs. 47 and 48, Plate XXIII, show this arrangement in elevation and plan. There the hanging bar is a light platfom on which a heavy lead weight is pivotted about the axis $i\,i$ on the points of two steel screws, which press up into a conical hole and V-slot in a bar j to which the weight is rigidly attached.

Another plan is to use a pair of light suspended platforms, in line with each other, and use them to carry a massive block by three sharp feet which press into a hole and V-slot on one platform, and a V-slot parallel to these on the other. This arrangement is shown in figs. 49 and 50.

But in both of these arrangements the friction at the pivots by which the weight rests on the hanging platform is a disadvantage, which is all the more felt because the platform tilts up through a considerable angle when displaced from its mean position. For this reason the writer prefers the very simple form shown in figs. 51 and 52. There the bob or heavy mass is a piece of lead rigidly fixed to the hanging bar. The effect of this is that when a horizontal displacement of the ground occurs, in the line of the bar, the centre of the bar does not remain at rest, but moves through a small determinate distance in the same direction as the ground.

Let M be the mass of the hanging piece (including the rigidly attached bob), and let Mk^2 be its moment of inertia about its central transverse axis. When the hanging piece is displaced, its motion is one of rotation about its instantaneous axis, which is always situated at the intersection of the suspending cords

(the point I in the sketch on p. 90). It is easy to show that, for any moderate displacement, this axis moves in a sensibly horizontal direction, and through the same distance as the centre of the bar. Hence the angular displacement of the bar is, very nearly, proportional to its linear displacement, and is equal to the latter divided by h, where h is the height of the instantaneous axis I above the bar. As regards its resistance to rotation, the hanging piece is therefore equivalent to a particle of mass M whose velocity-ratio relative to the centre of the bar is sensibly constant, and equal to $\frac{k}{h}$. Hence the extra inertia due to rotation is $\frac{Mk^2}{h^2}$, referred to the centre of the bar.

When a horizontal displacement of the supports occurs, we may consequently consider the whole system as consisting of a particle M together with a connected particle $\frac{Mk^2}{h^2}$, of which only the first is effective in producing steadiness, although both are constrained to share the same motion. The piece will therefore suffer an acceleration in the same direction as the acceleration of the supports, and bearing to it the ratio $k^2 : h^2 + k^2$. The centre of the bar will be displaced in the direction of the displacement of the supports, and in the same proportion; and any measurements of earthquake motion which are taken with reference to the centre of the bar as a datum-point must be multiplied by $1 + \frac{k^2}{h^2 + k^2}$ to find the true displacement of the ground. When the bob is a lump of lead whose dimensions are small compared with the length of the hanging bar, this factor differs very little from unity.

Two light bars with dense rigidly attached bobs, and suspended by silk threads so as to swing at right angles to each other, form an excellent two-component seismograph, especially suitable for the measurement of large earthquakes. The complete absence of joints makes the frictional resistance exceedingly small: in this respect the method of suspension now under examination contrasts very favourably with most of the methods which have been described in Chapters II and III. Moreover the construction, and also the adjustment, is very simple. For large earthquakes the method of recording shown in fig. 51 will probably be found suitable. A light pointer l is forked so as to enclose the hanging bar, and is jointed to the bob at its centre. Its end m rests on a smoked-glass plate, the pressure being regulated by a counterpoise n. The plate should be set in rotation by an earthquake, by means of a seismoscope which may conveniently be somewhat wanting in sensibility, in order that it may act only when the motion becomes tolerably severe. The record will be *less* than the true motion, in the ratio given above.

Fig. 52 shows an instrument of the same kind in plan, but with a multiplying index p, which is pivotted to the ground on a vertical axis o, and receives its motion by having a bent-up end which gears into a slotted plate q fixed to the bob.

Fig. 53 is a sketch of a curious form of double-freedom seismometer, in which a somewhat similar method of suspension is used. The base *S*, which is fixed, is an equilateral triangle, at the corners of which there are three conical cups forming sockets for three legs *r r r* of equal length. These legs press up into three other sockets in the plate *s*, which are placed so as to form an equilateral triangle of half the linear dimensions of the base. The height of *s* from the base is 0.866 times the distance between the base sockets. The plate *s* carries a massive bob *w*, slightly beneath it. The plate is then in nearly neutral (somewhat stable) equilibrium with respect to small motions in any azimuth. It is necessary here to invert the system and use struts instead of ties, since a plate hung by three crossed cords would be azimuthally unstable. Two of the legs are made with loops to allow the three to cross each other. By adding a multiplying pointer to record the displacements of the base with respect to the centre of the plate, we should obtain a compact form of double-freedom seismograph, whose frictional resistance (though much greater than that of the single-freedom instrument just described) could probably be kept within reasonable limits.

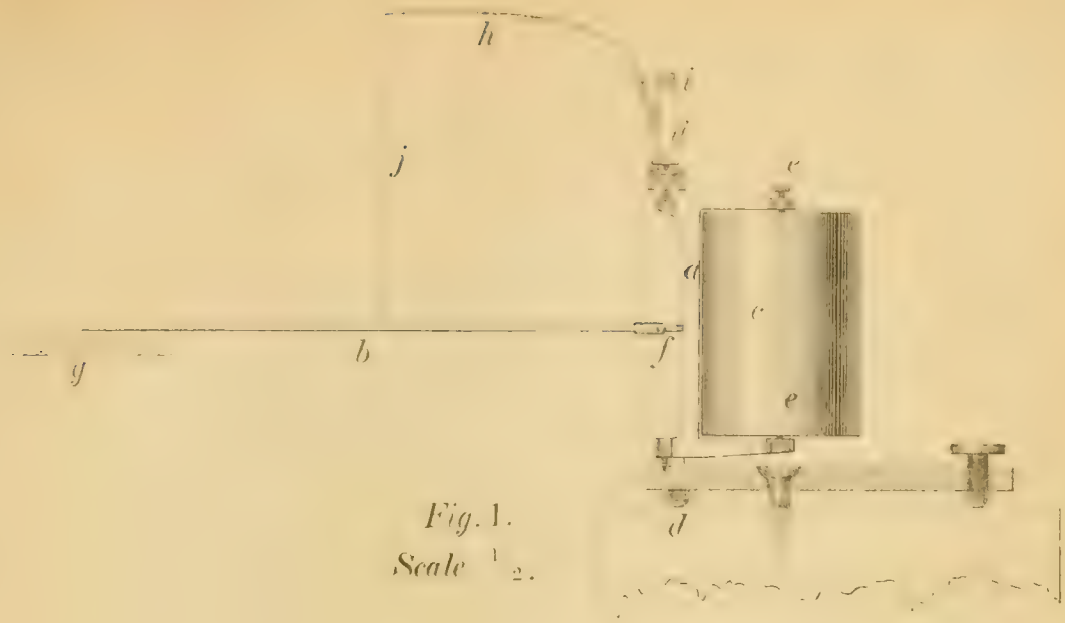


Fig. 1.
Scale $^1/_2$.

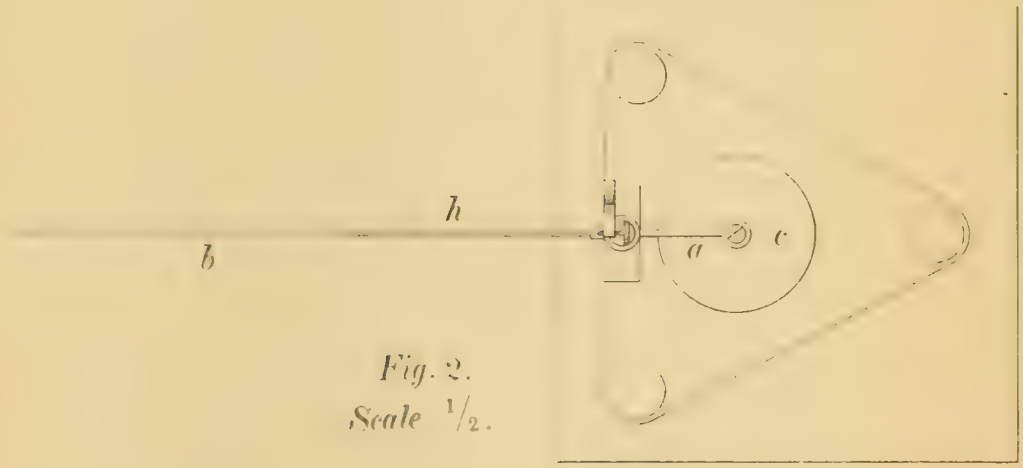


Fig. 2.
Scale $^1/_2$.

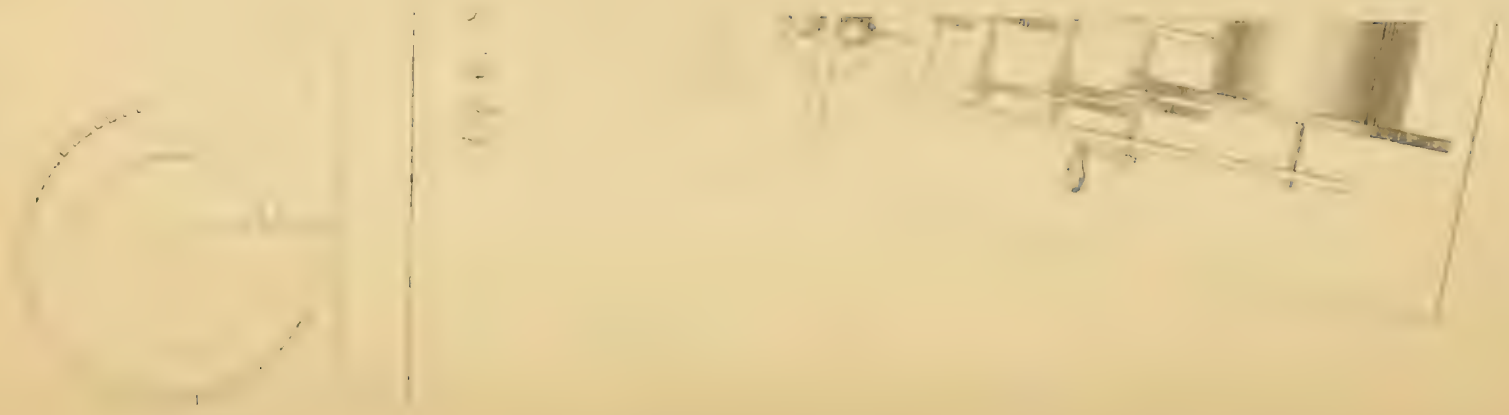
c

g

b

Fig. 3
Scale $^1/_8$.

l



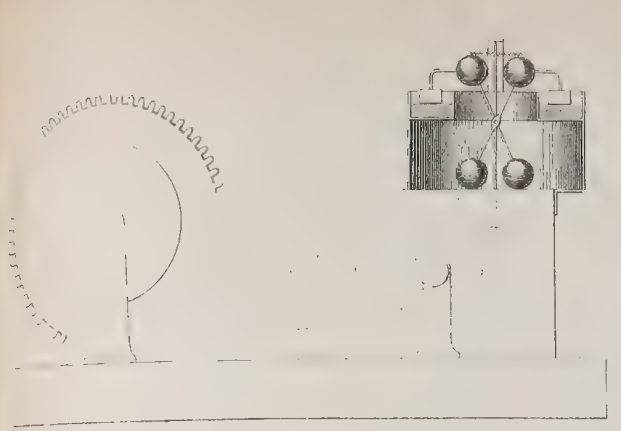


Fig. 6. Scale

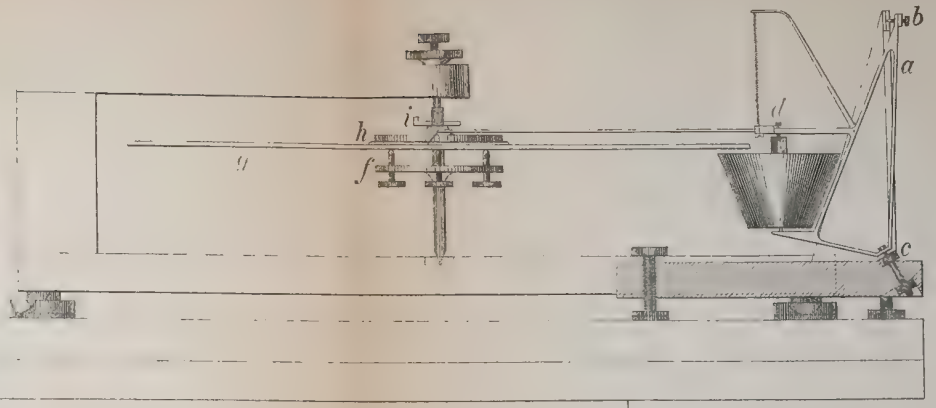


Fig. 5. *Scale*

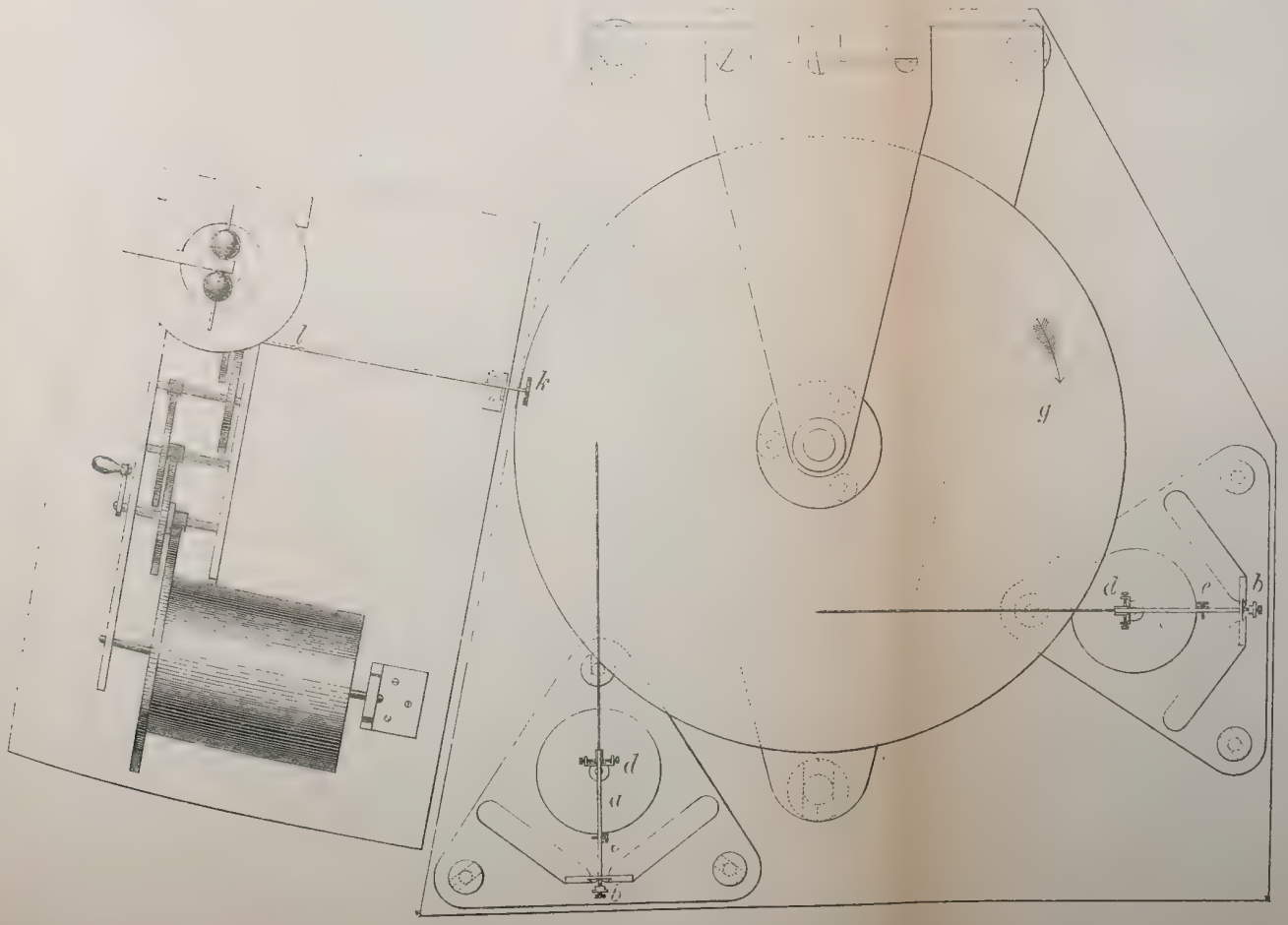


Fig. 4. Scale $^1/_4$

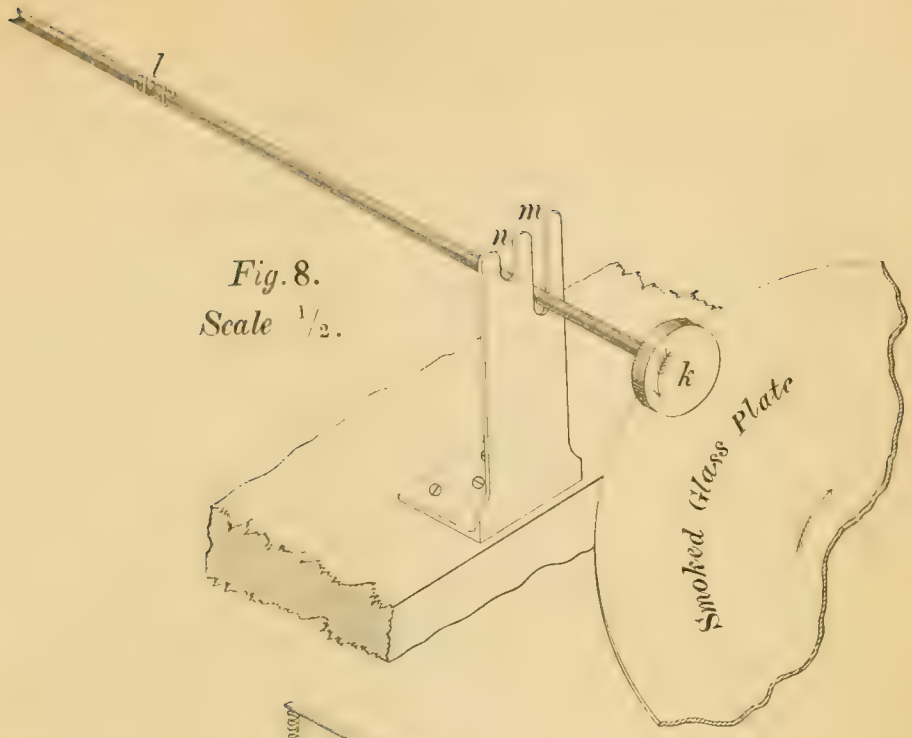


Fig. 8.
Scale $^1/_2$.

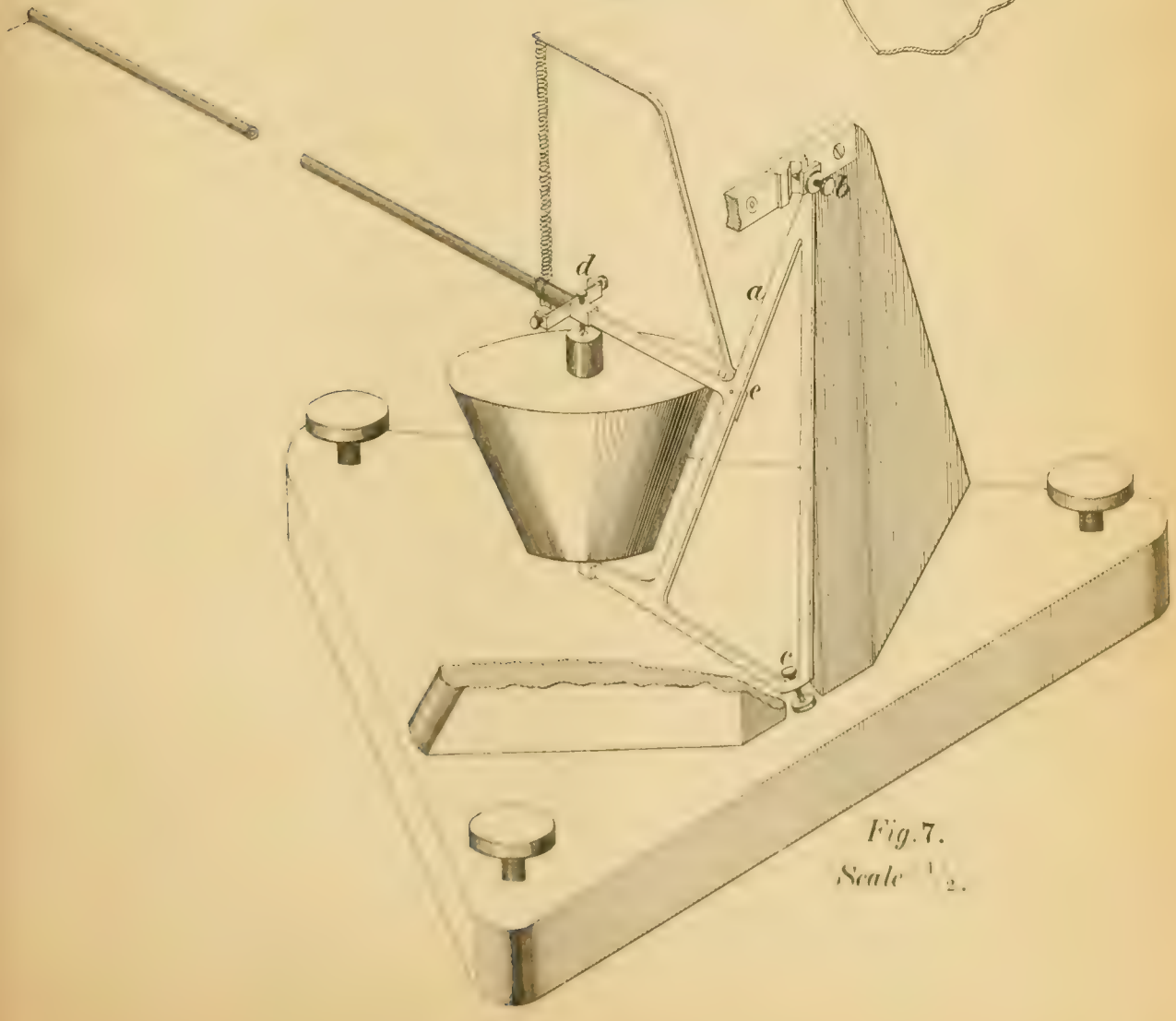


Fig. 7.
Scale $^1/_2$.

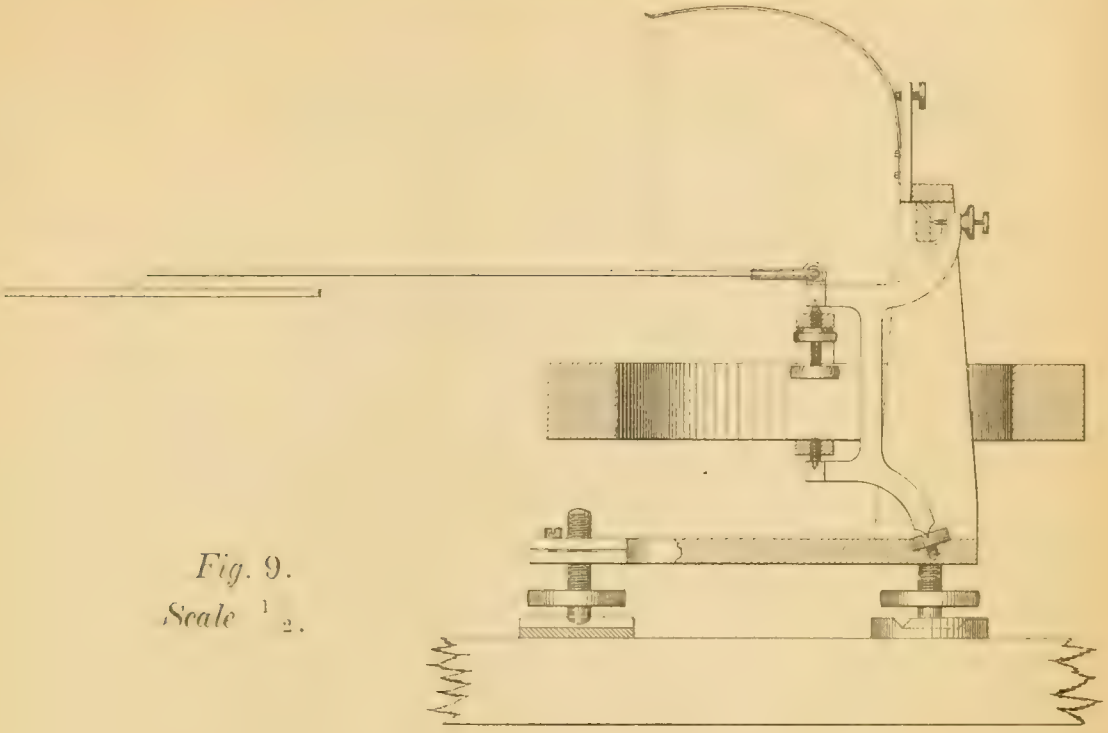


Fig. 9.
Scale $^{1}/_{2}$.

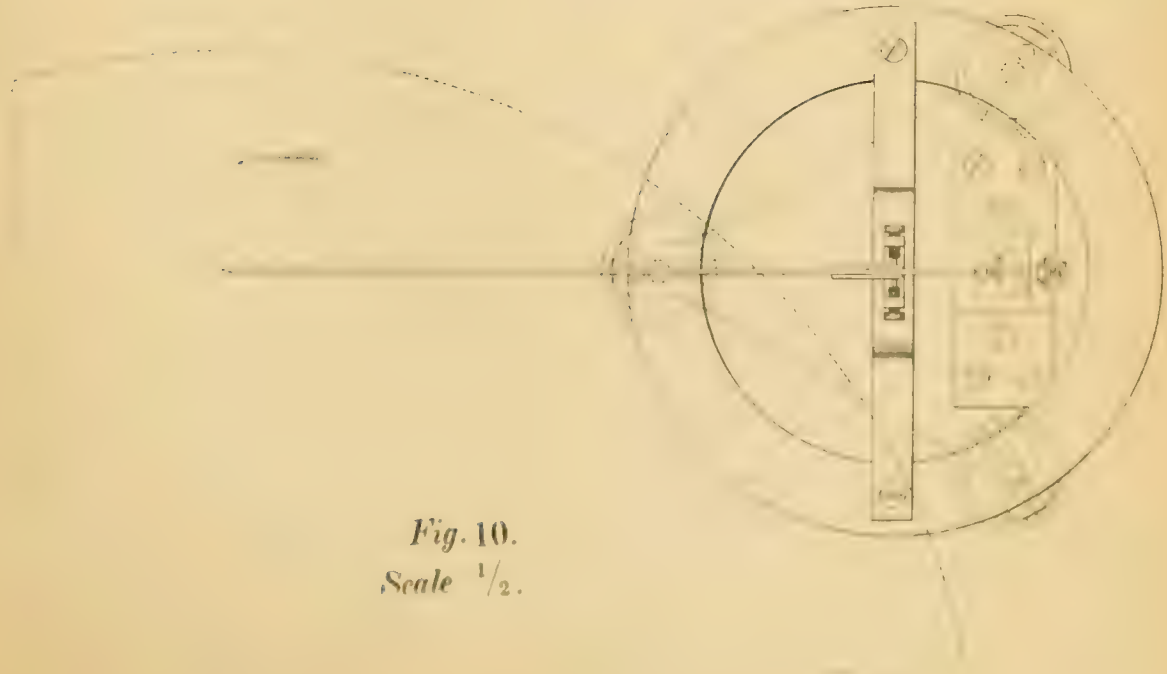


Fig. 10.
Scale $^{1}/_{2}$.

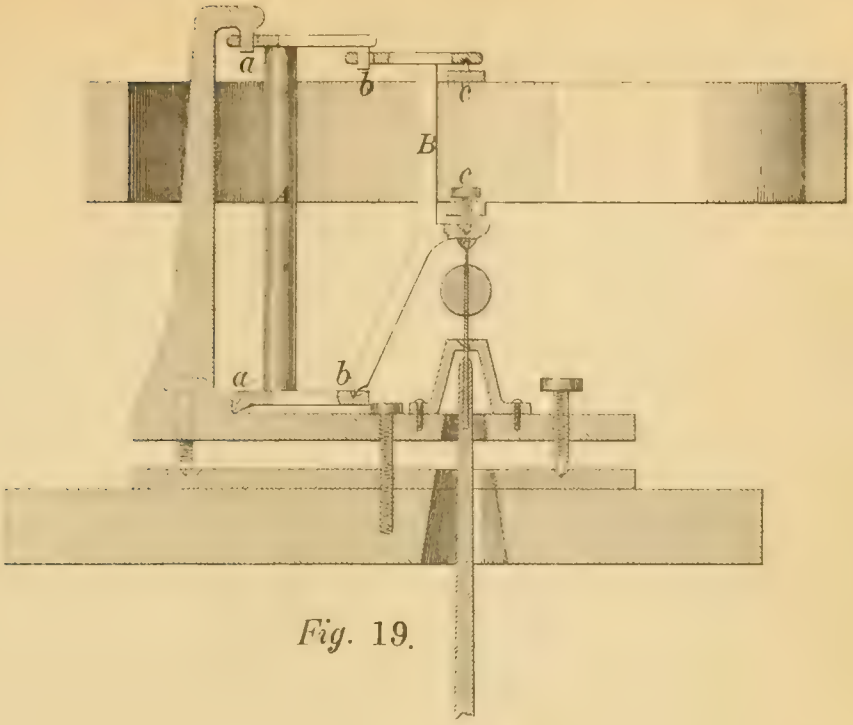


Fig. 19.

Fig. 20.

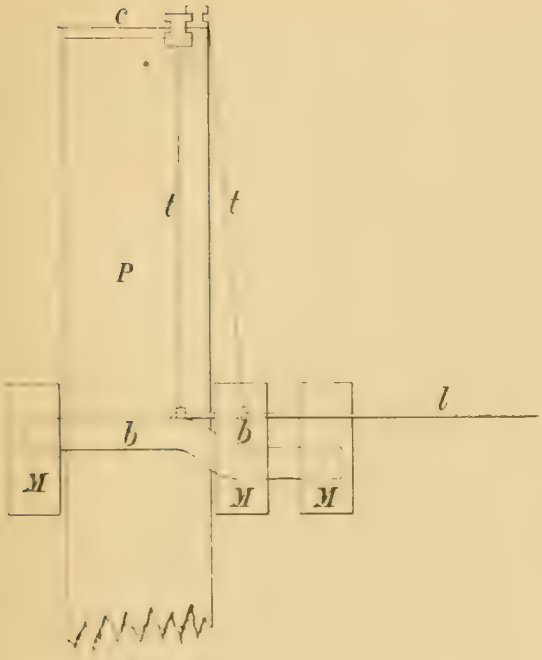


Fig. 11.

F

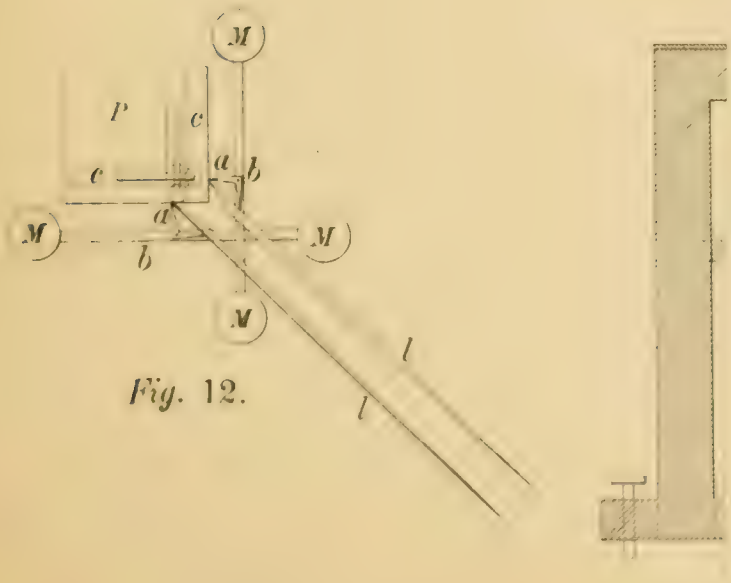


Fig. 12.

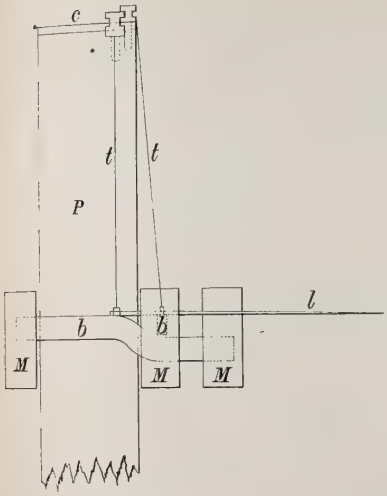


Fig. 11.

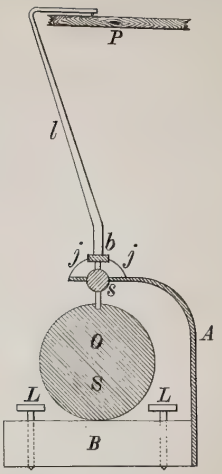


Fig. 21.

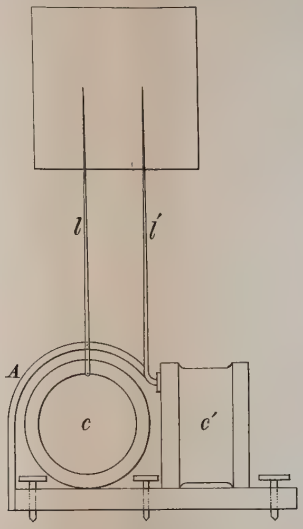


Fig. 23.

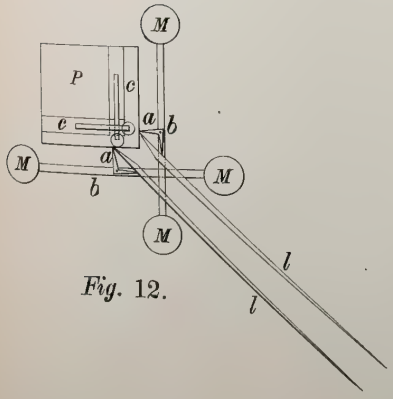


Fig. 12.

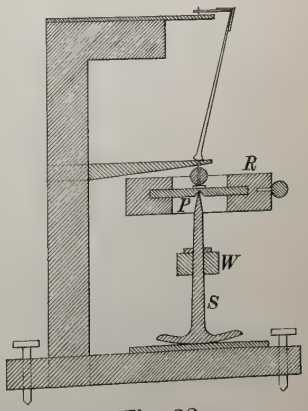


Fig. 22.

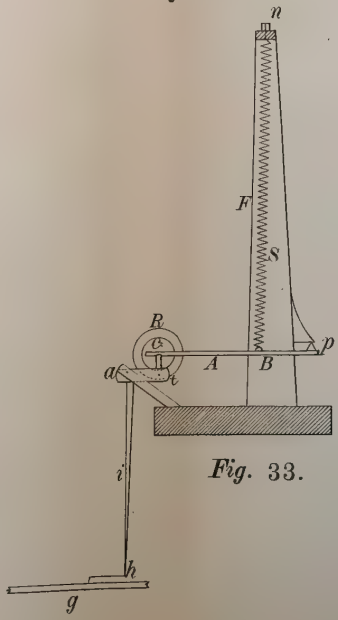


Fig. 33.

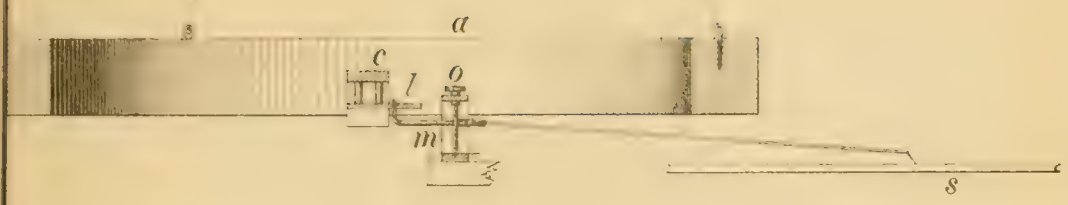


Fig. 27.
Scale $^1/_5$

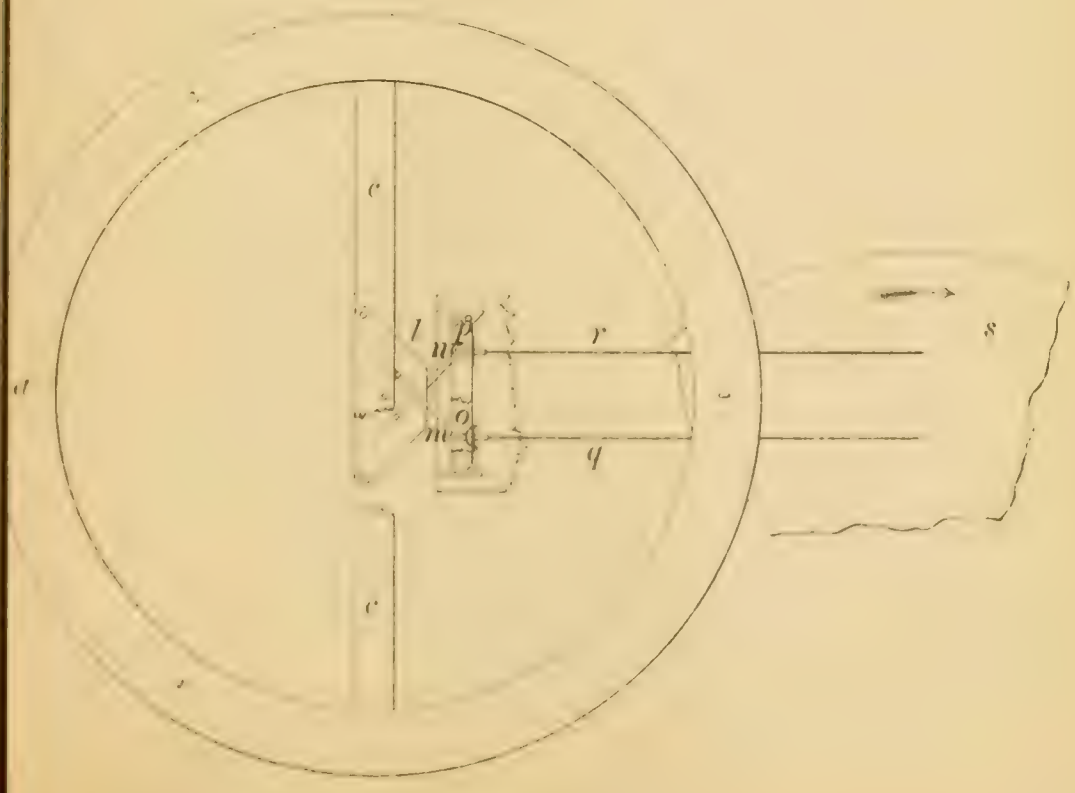


Fig. 28. Scale $^1/_5$

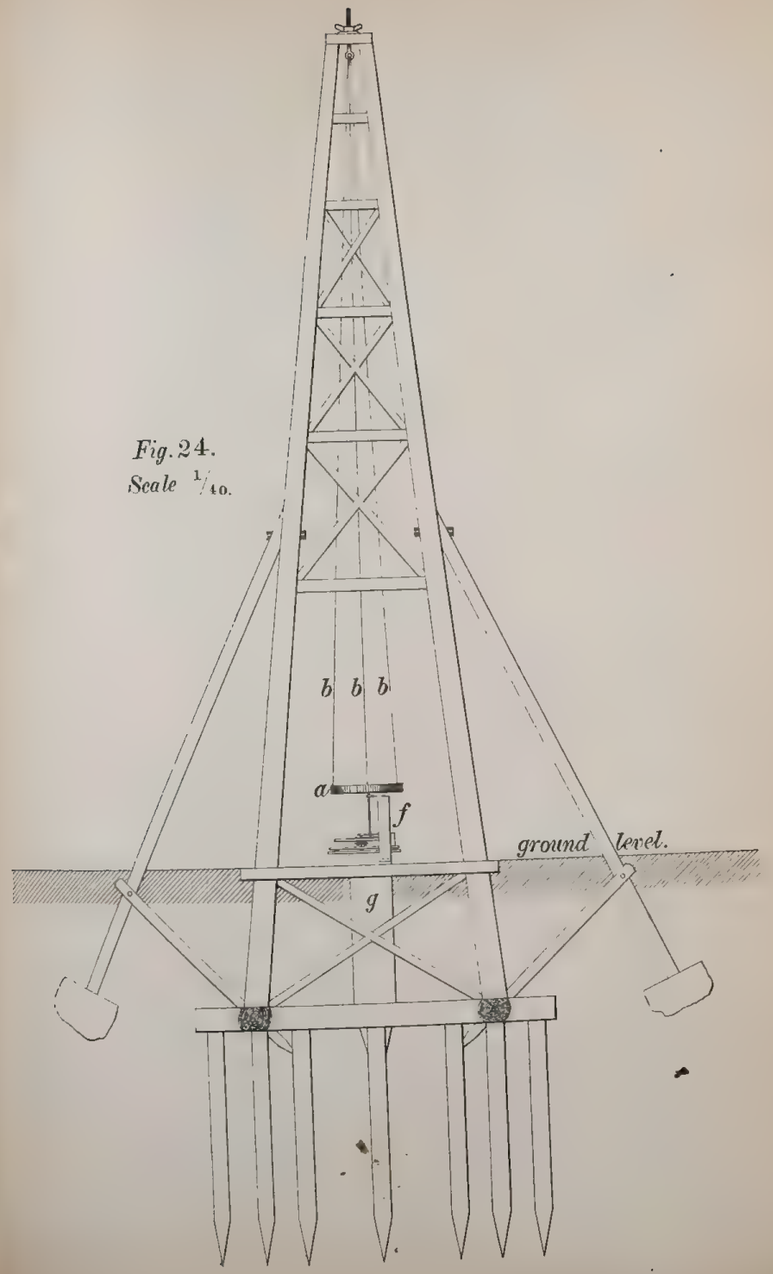


Fig. 24.
Scale 1/40.

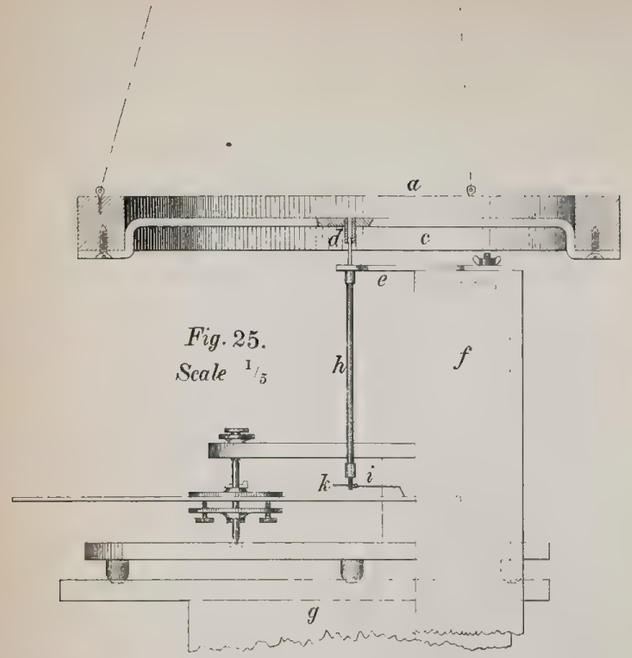


Fig. 25.
Scale 1/5

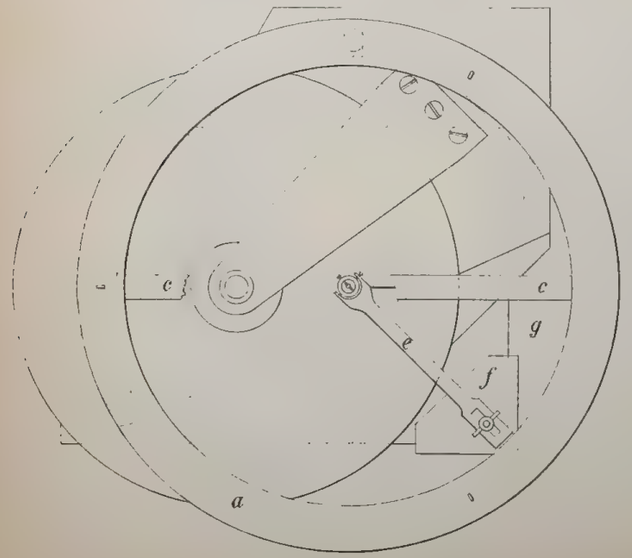


Fig. 26. Scale 1/5

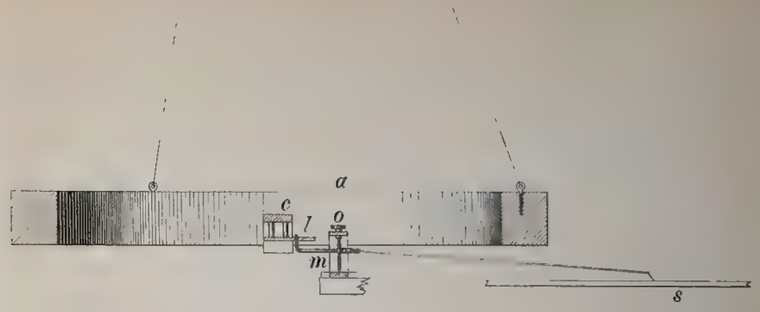


Fig. 27.
Scale 1/5

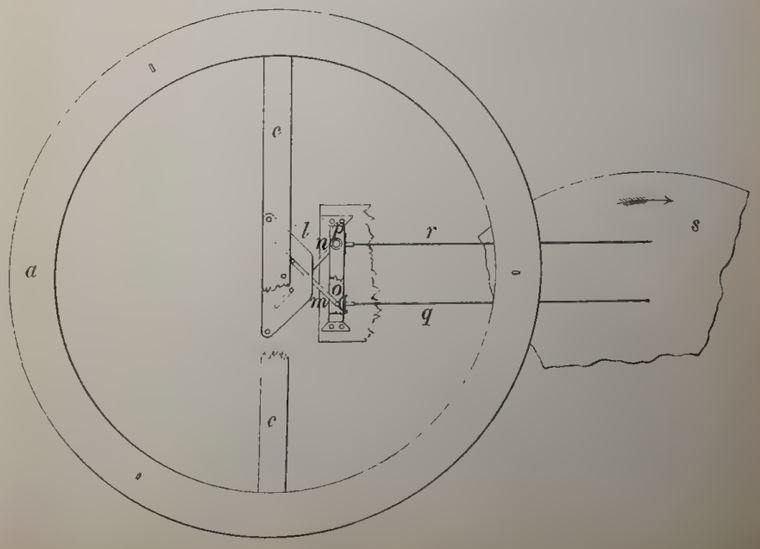


Fig. 28. Scale 1/5

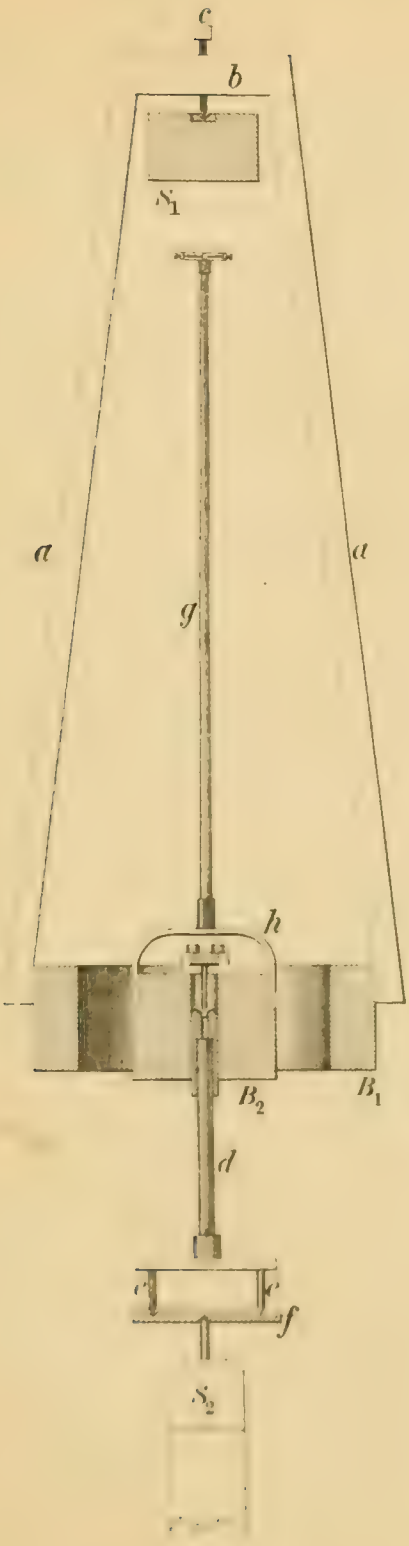


Fig. 29. *Scale* $\frac{1}{4}$.

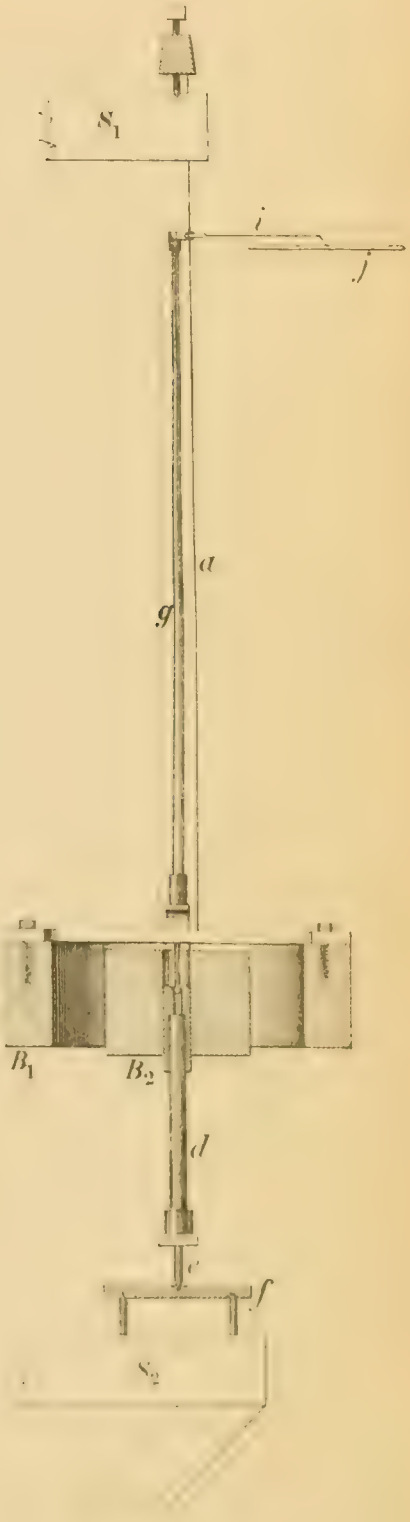


Fig. 30.

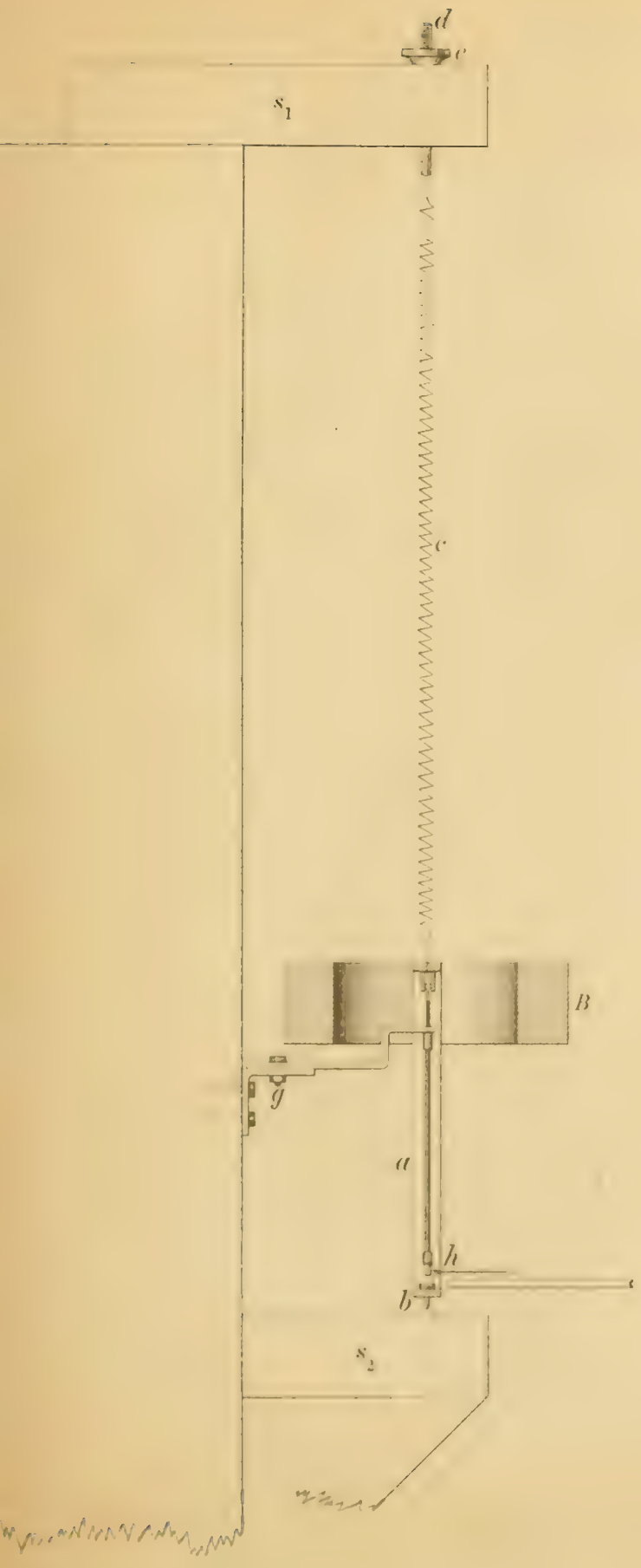
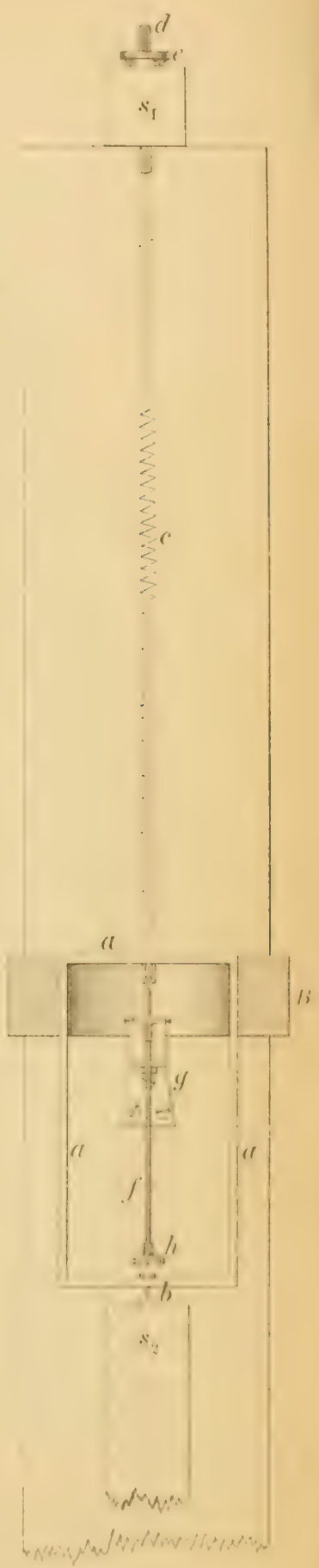


Fig. 31.

Scale 1/4.



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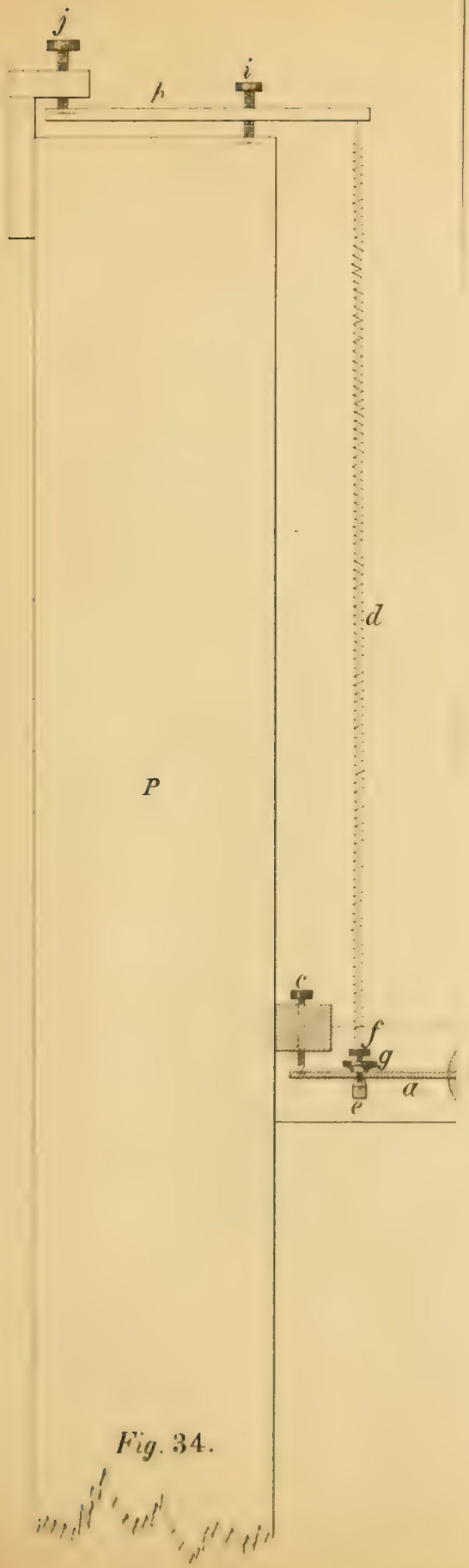
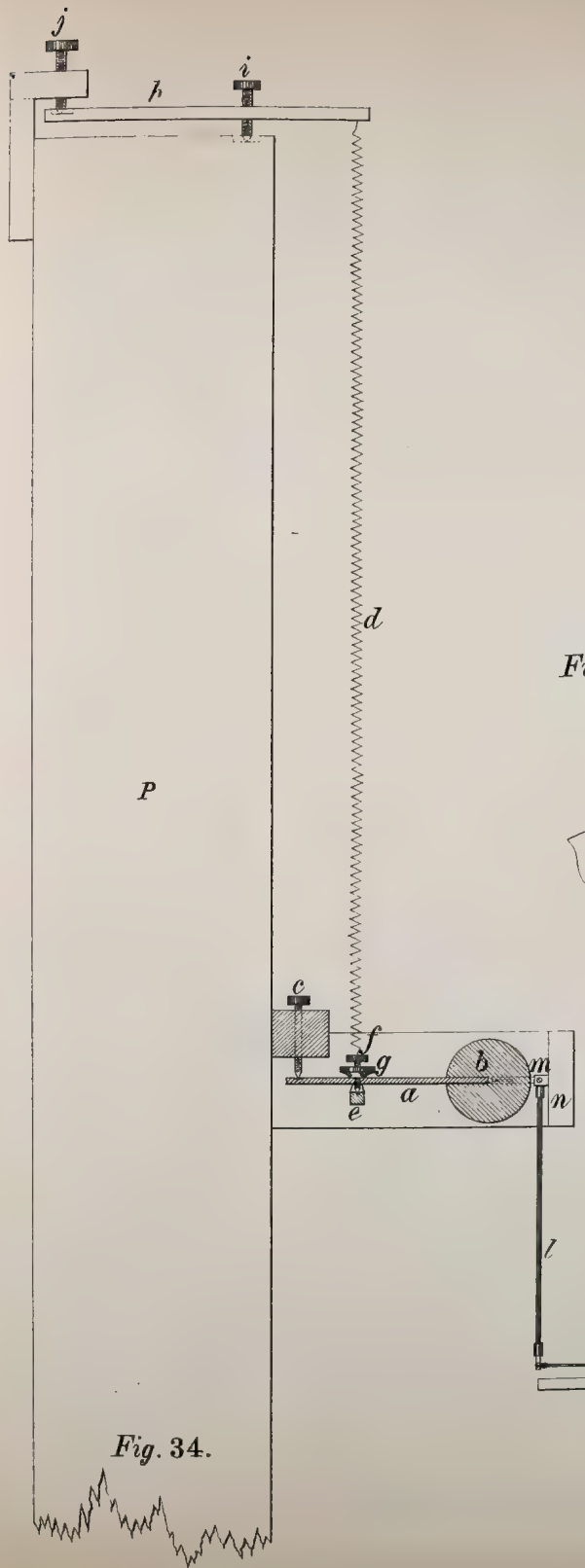


Fig. 34.



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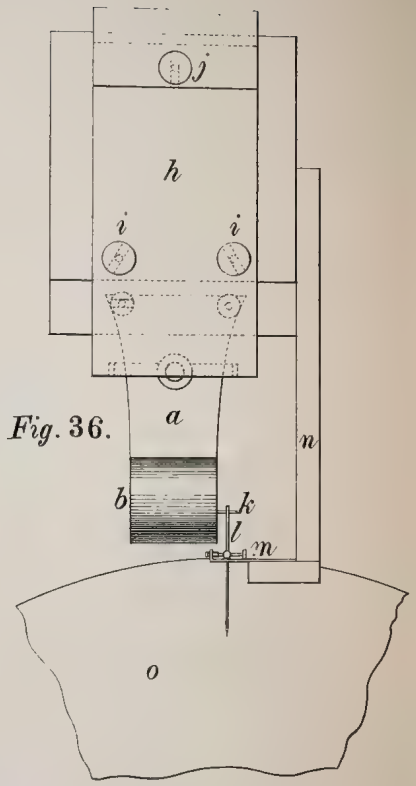

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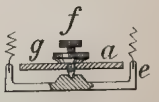


Fig. 37.

Scale 1/4.

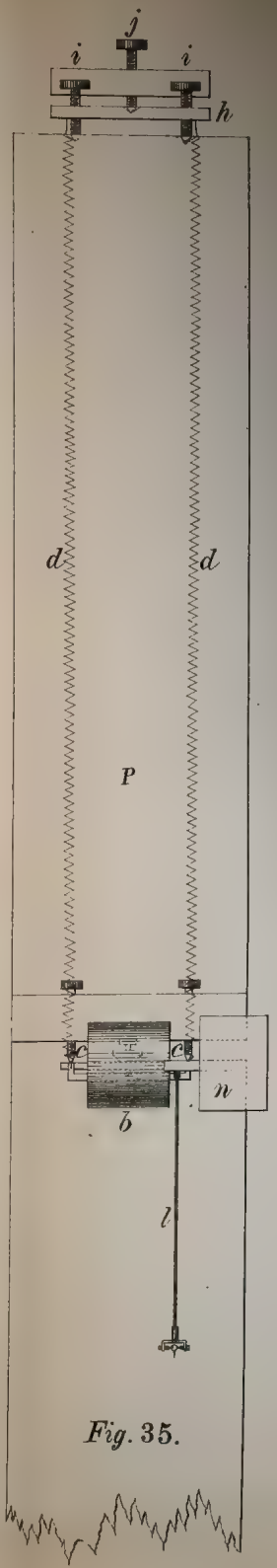
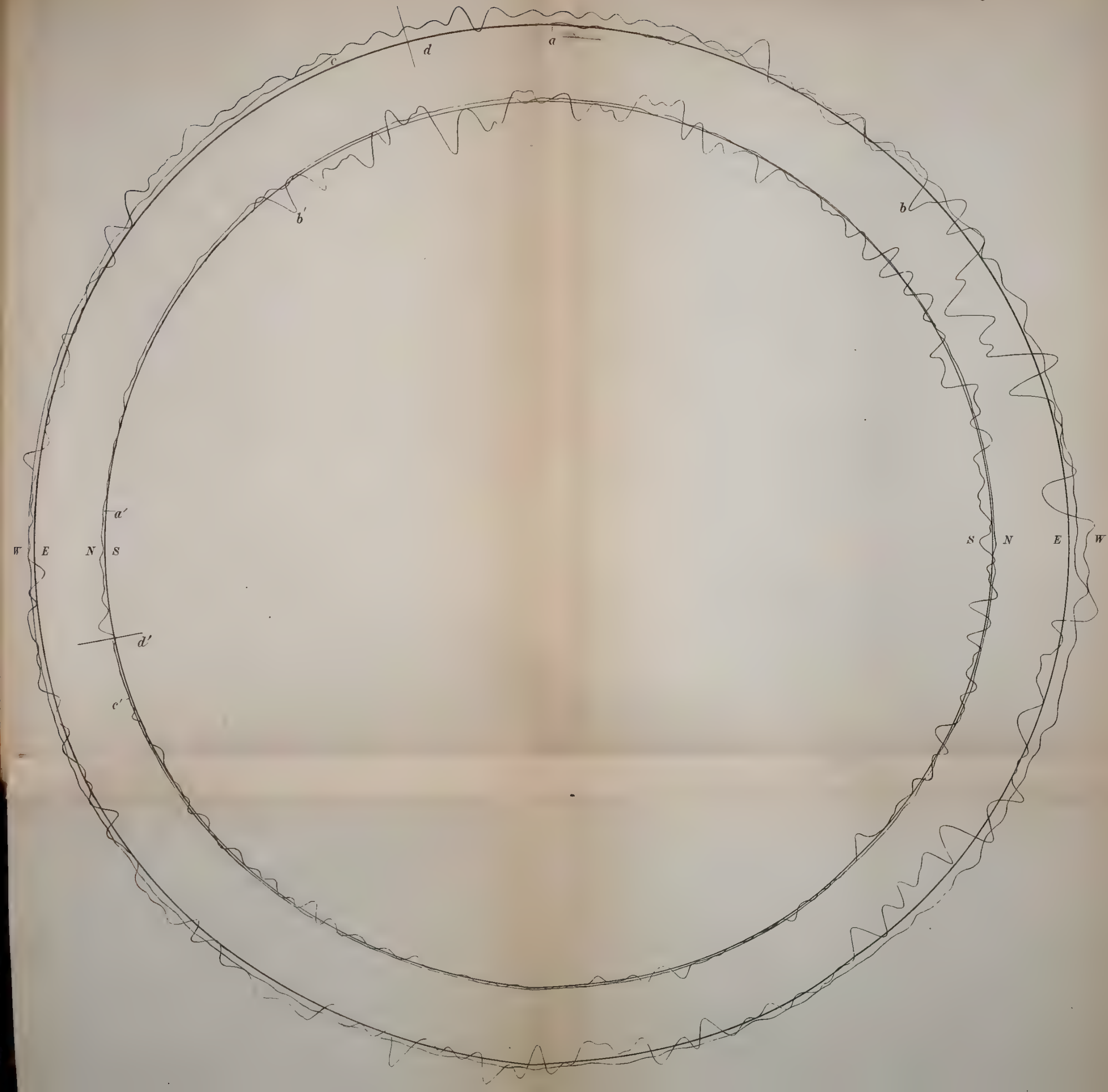


Fig. 35.

Measurement. Plate XII.

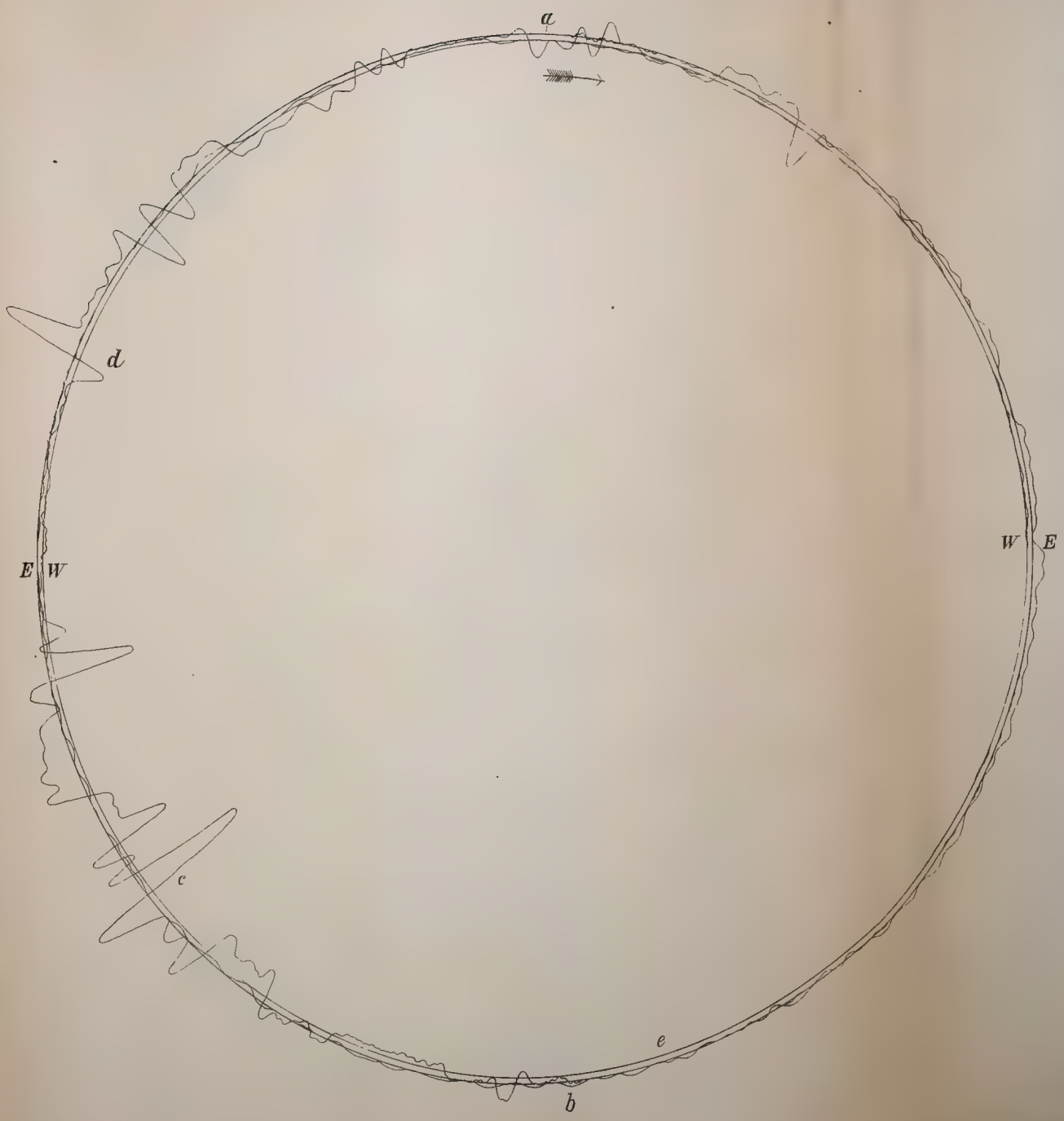
a
W E
E W
c
b

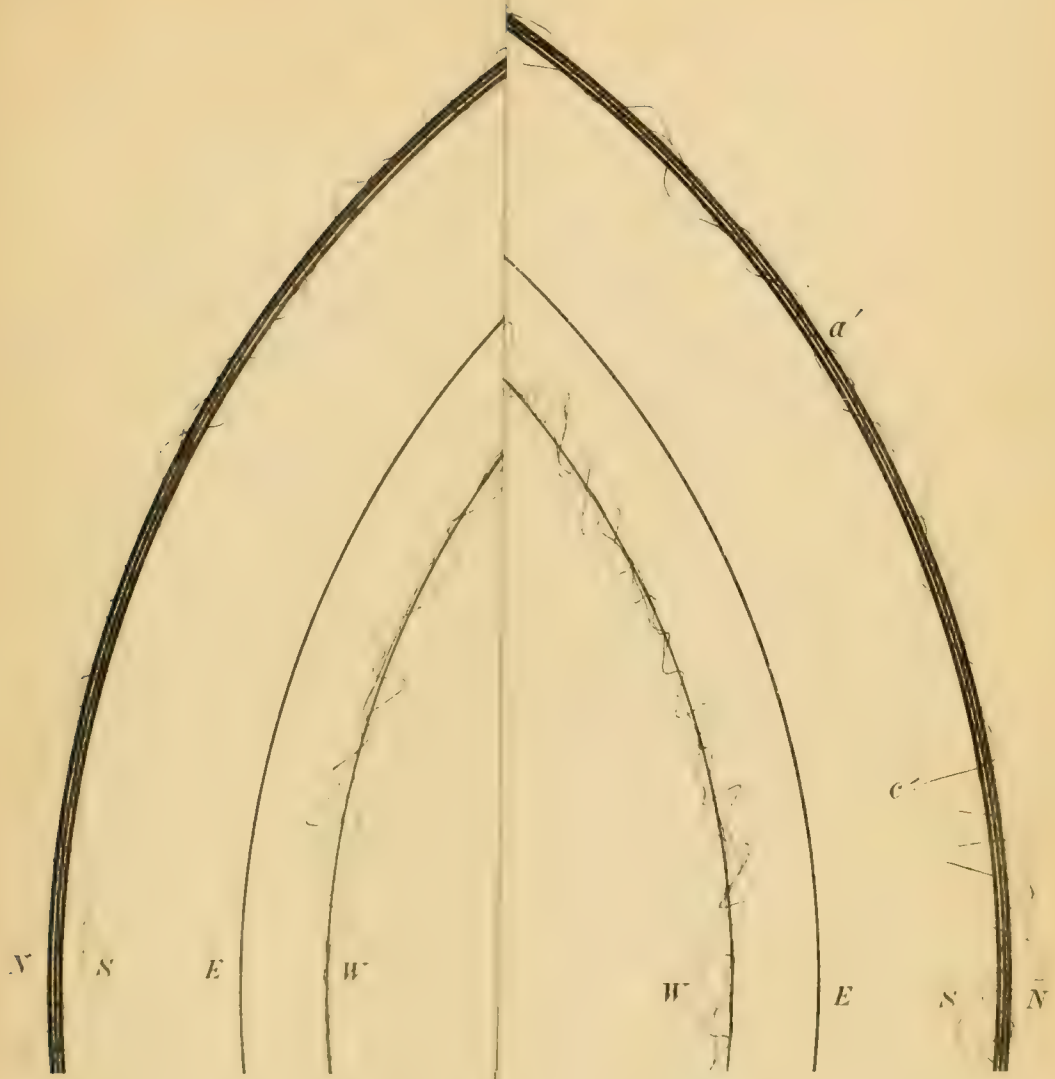
b

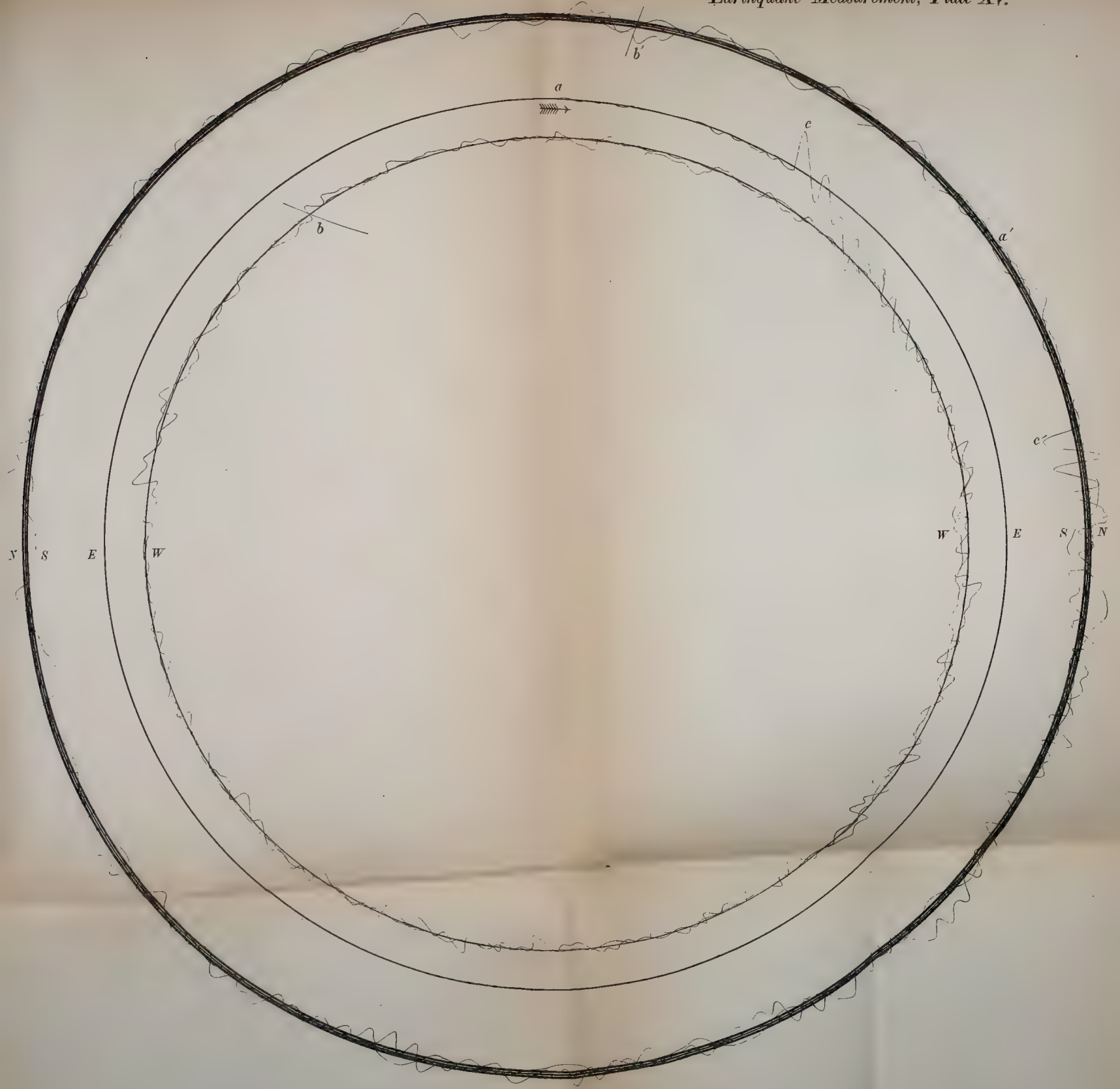

a
d
c
b
b'
a'
W
E
N
S
d'
c'
S
N
E
W

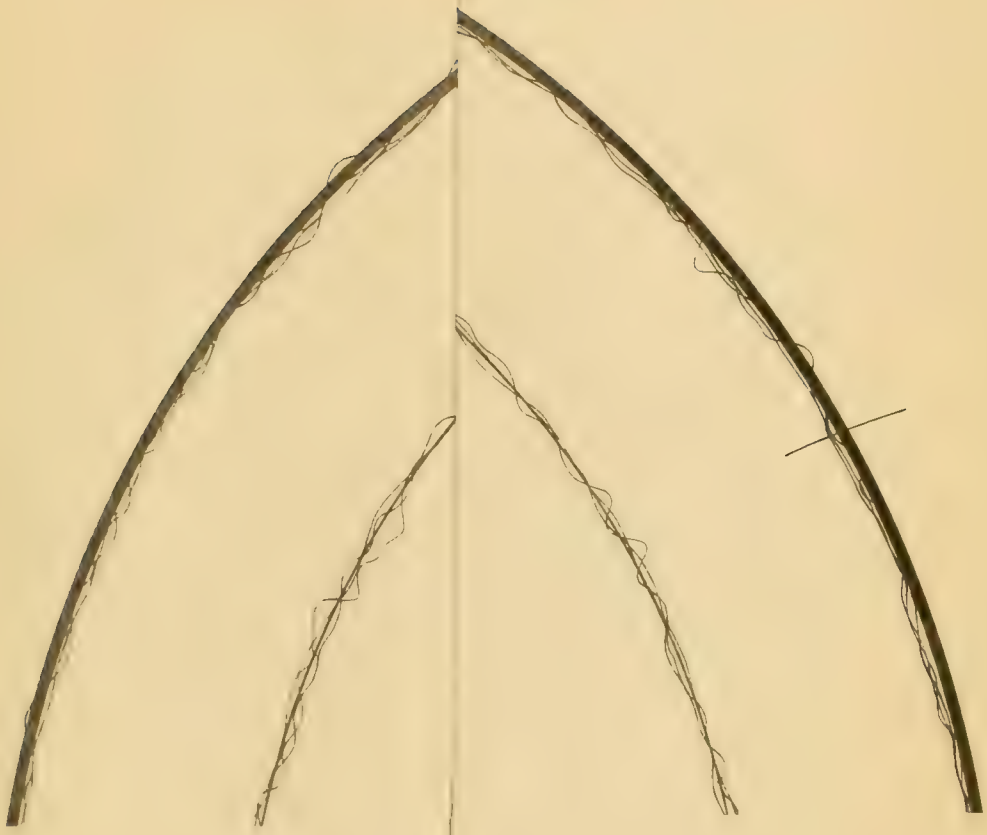
d
E
W
c
b

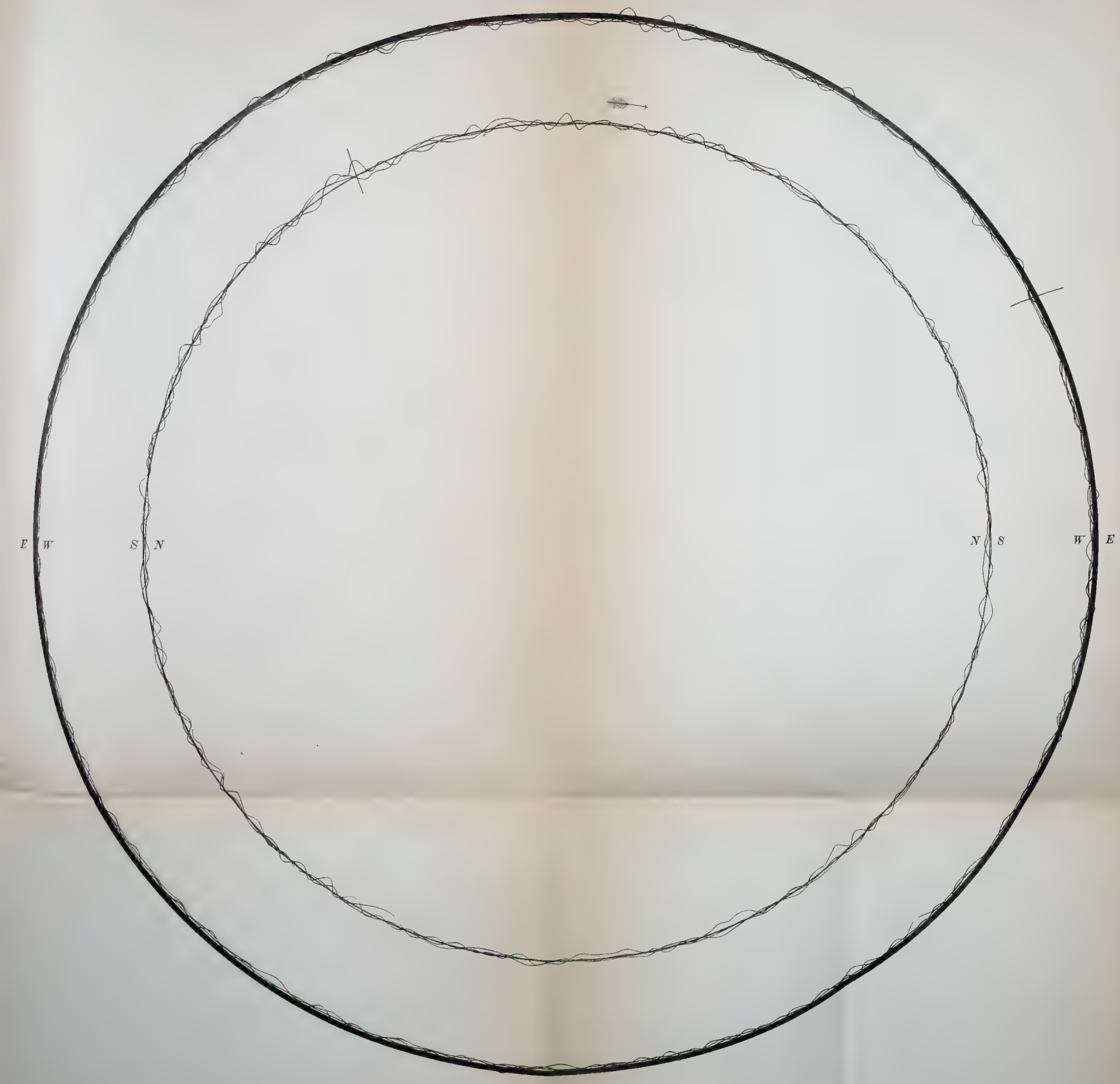
Earthquake Measurement, Plate XIV.



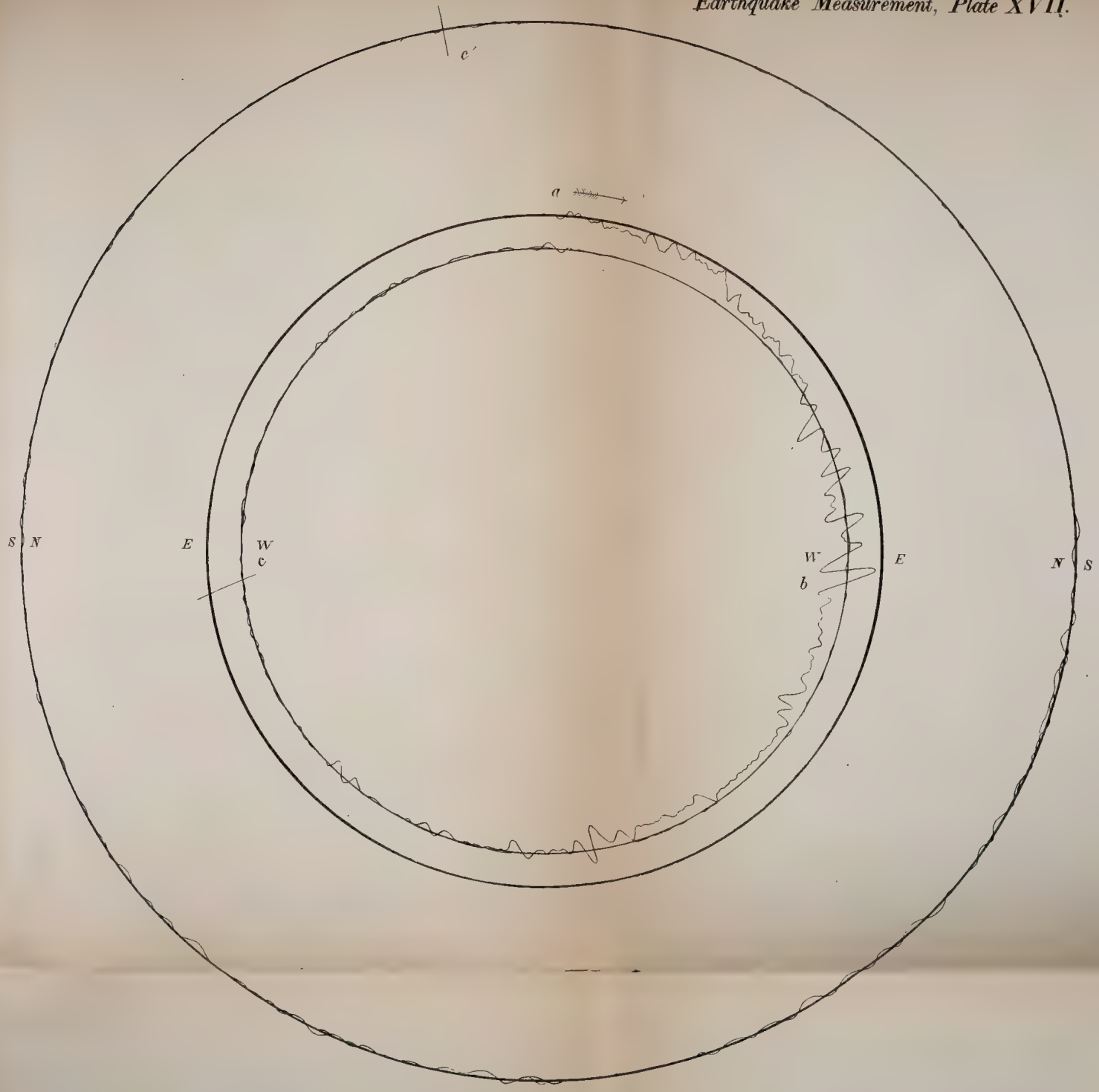

a′
C
N
S
E
W
W
E
S
N

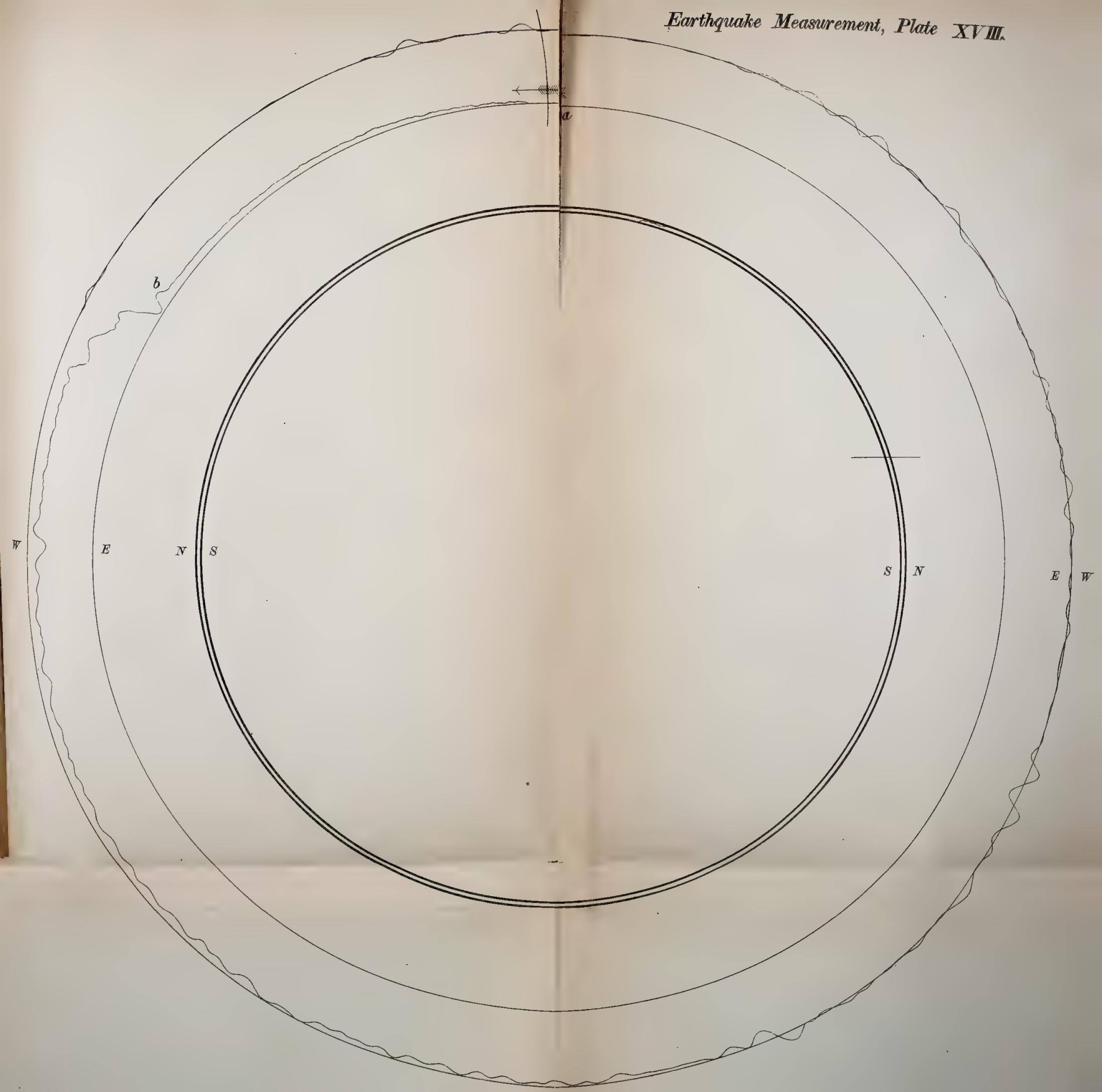

a
b'
b
c
a'
c'
W
E
S
N
W
E
S
N




E W
S N
N S
W E

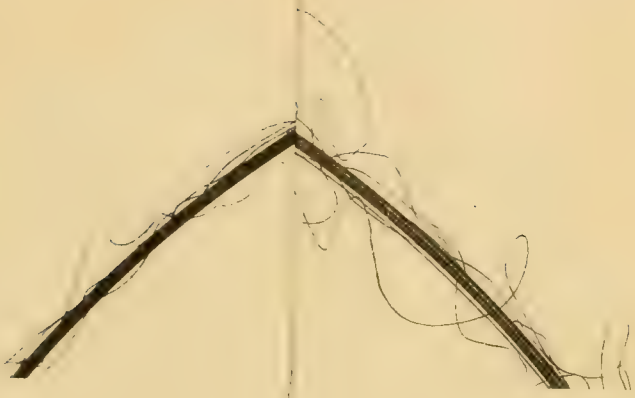
S


c'
a
S
N
E
W
c
W
E
b
N
S

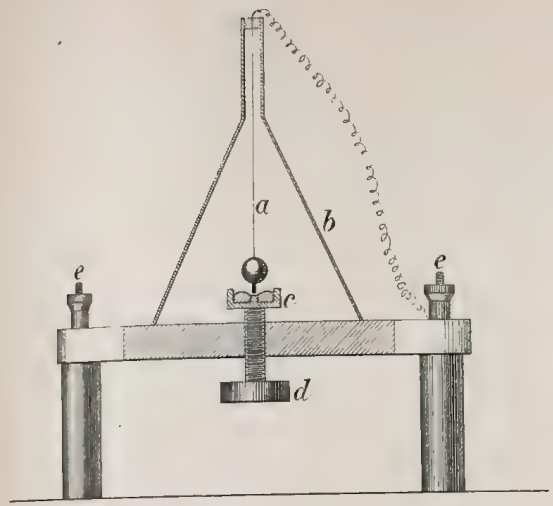

a
b
W
E
N
S
S
N
E
W

12
13
14
15
16

a
b
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
W E
N S
S N
E W



N
W
E
S
E 30° N.



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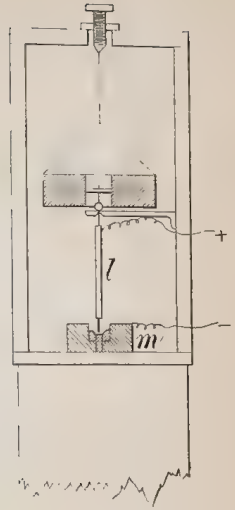

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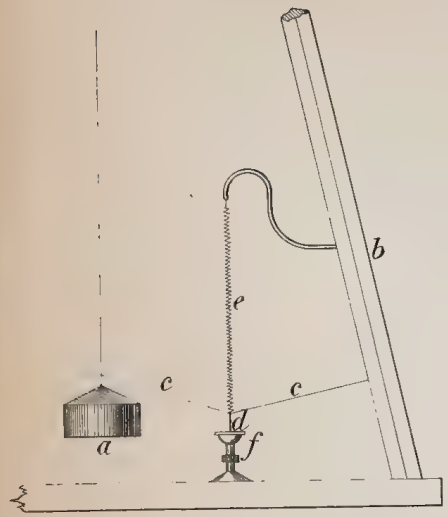

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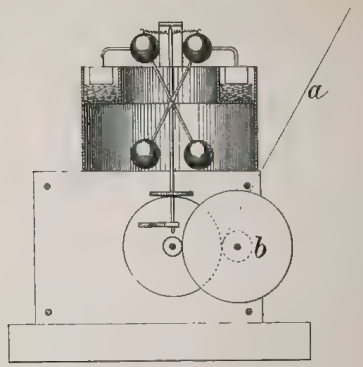

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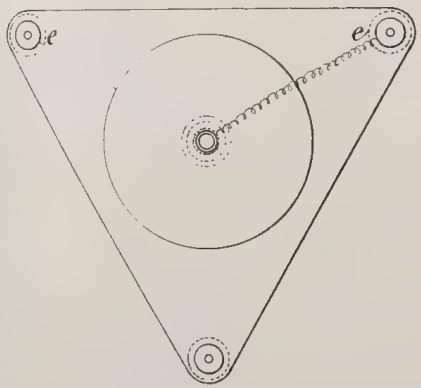
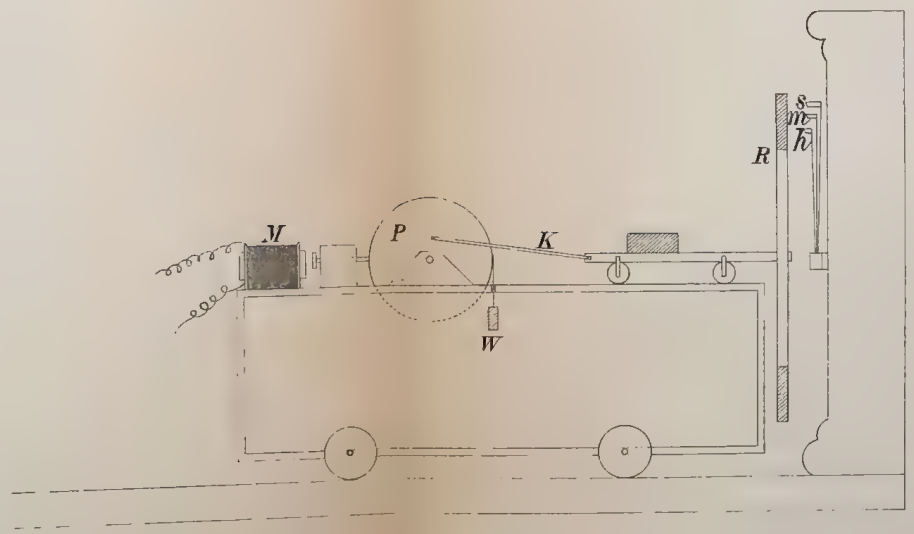


Fig. 39.

Fig. 40.



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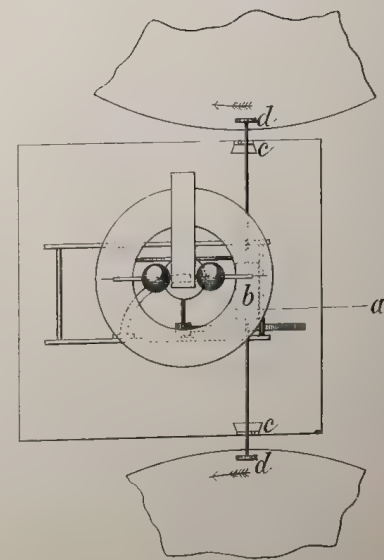

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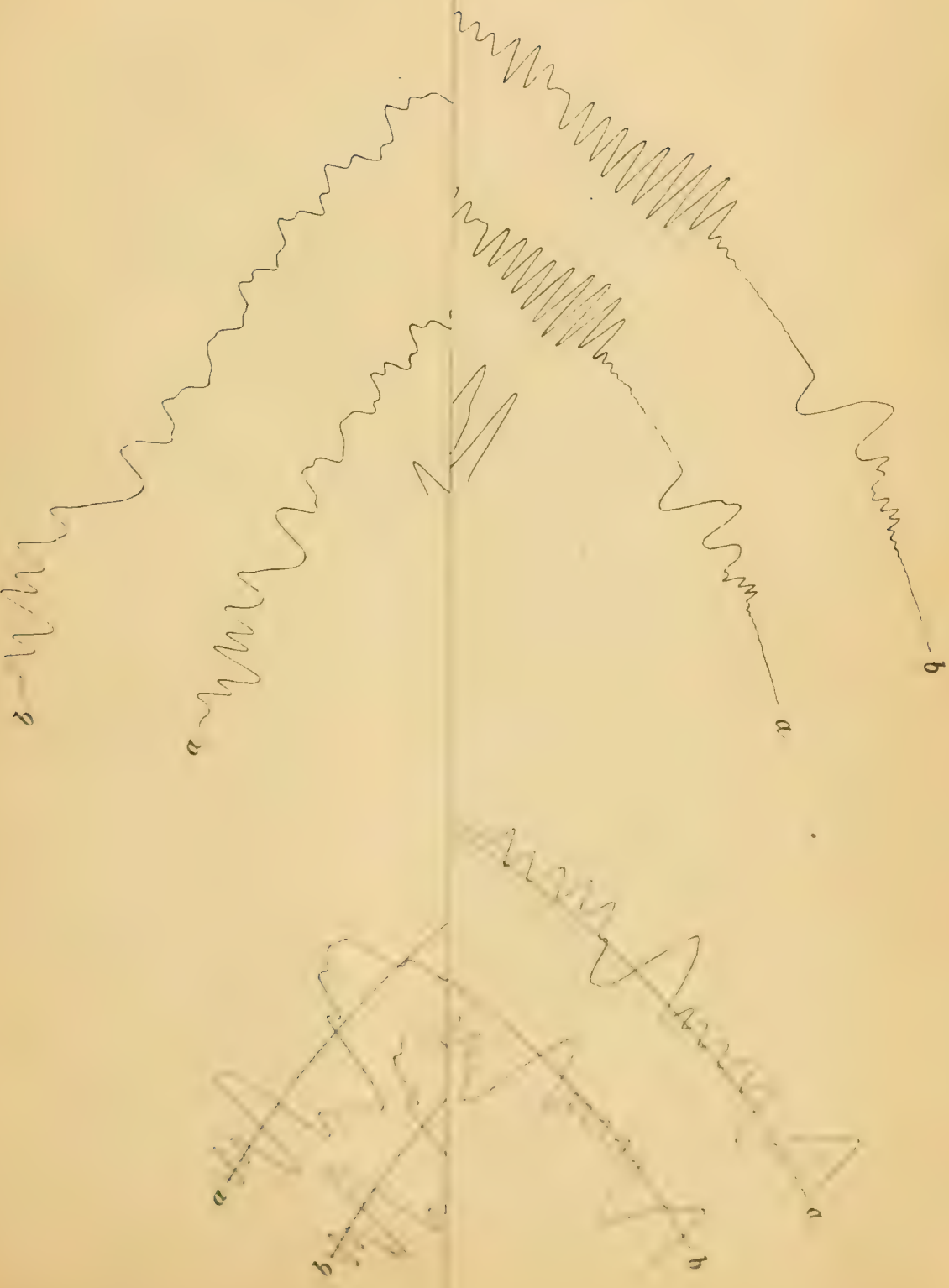
a
b
a
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a
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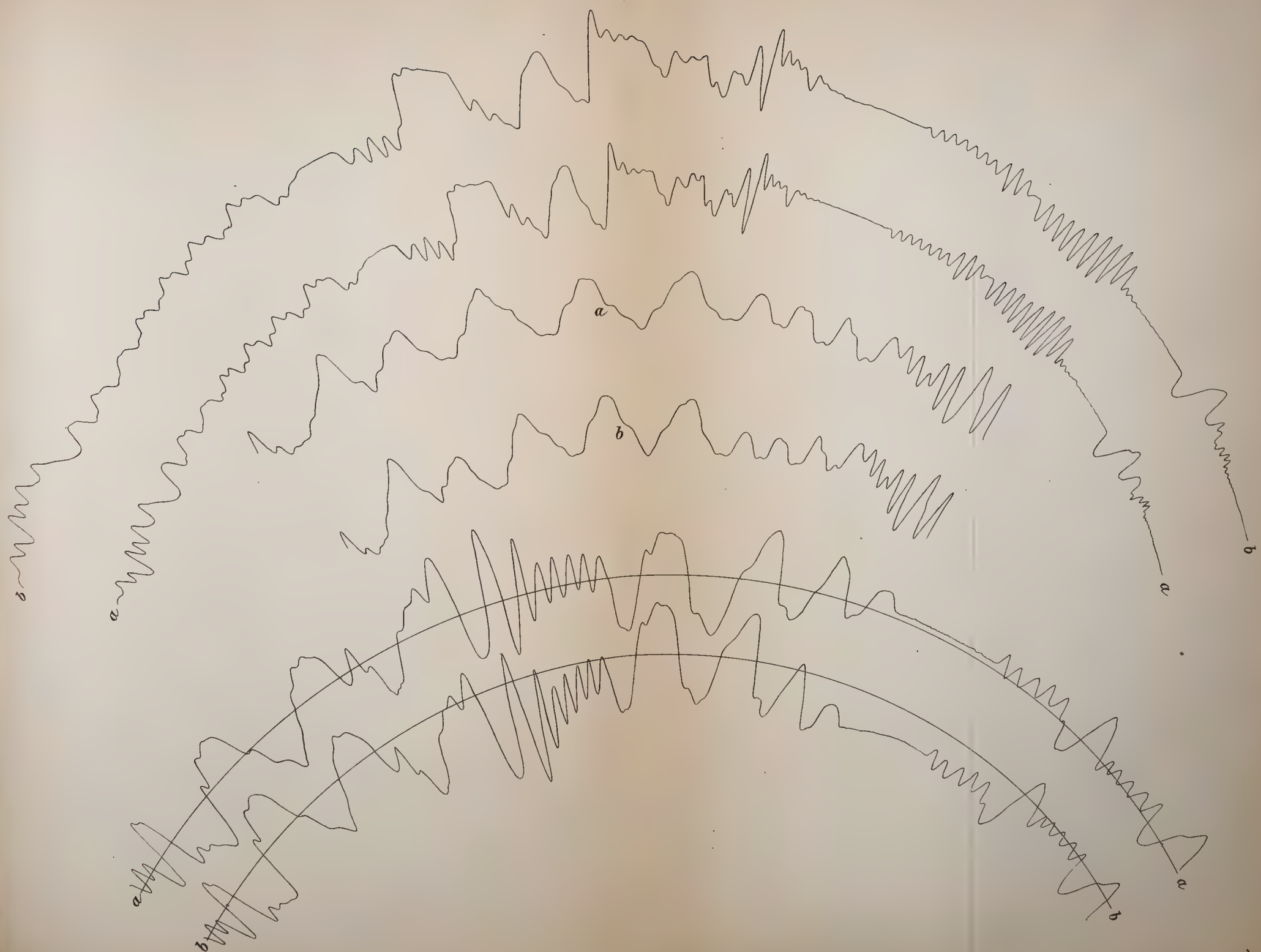
a
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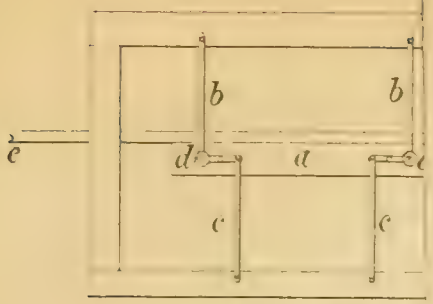

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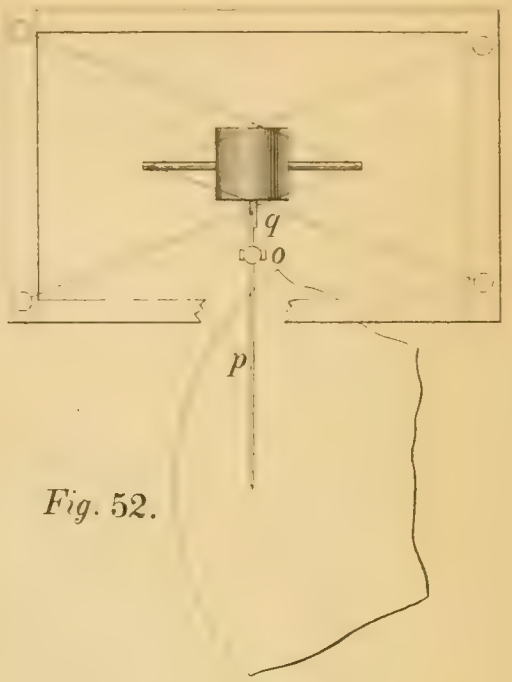

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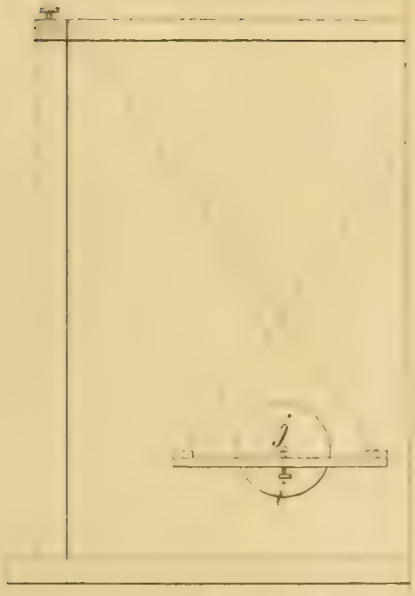

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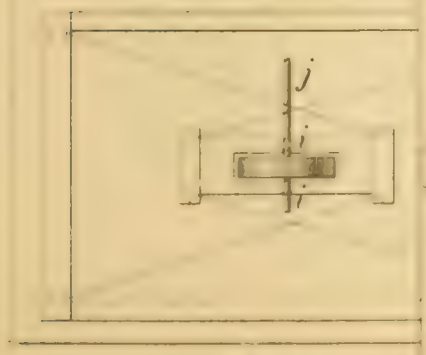

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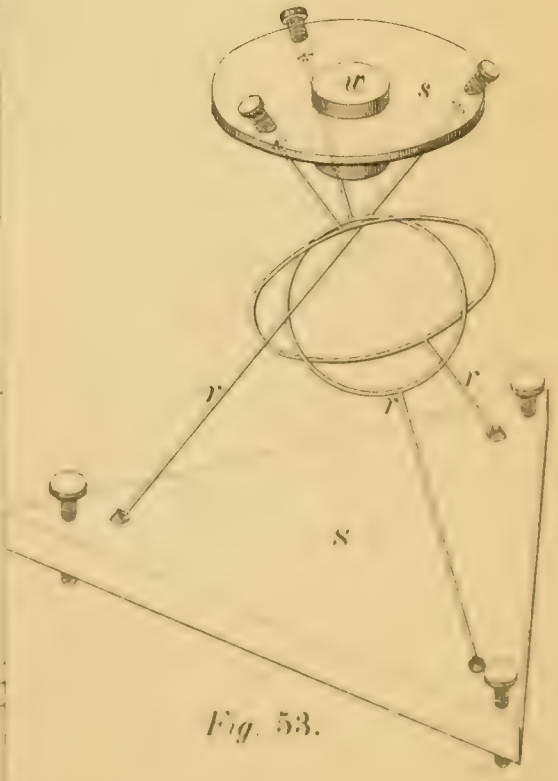

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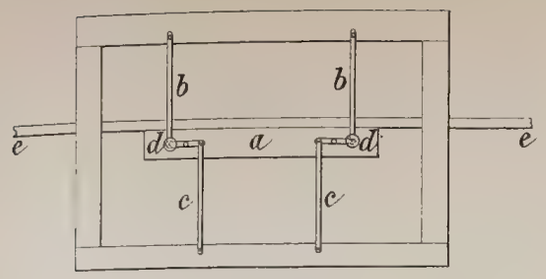

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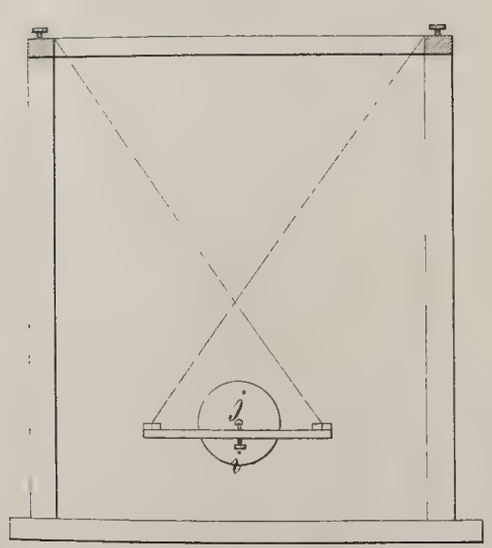

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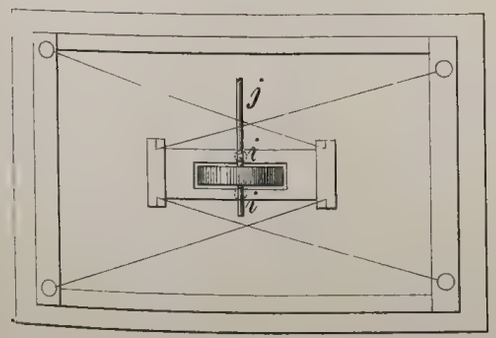

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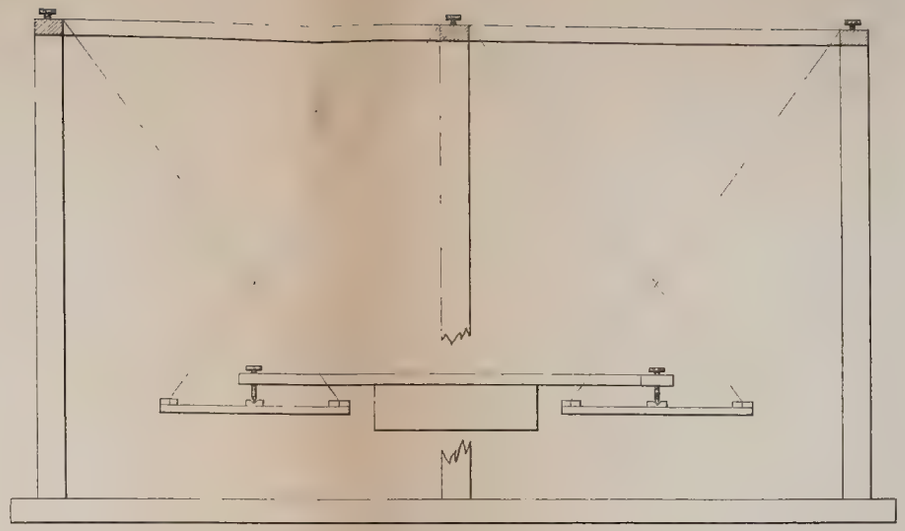
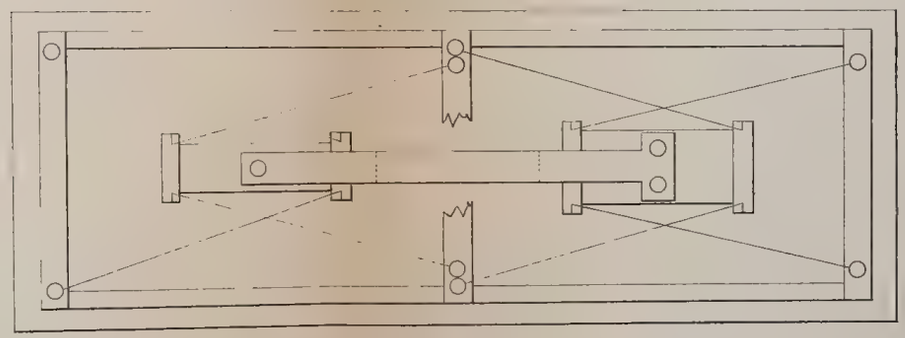


Fig. 49.



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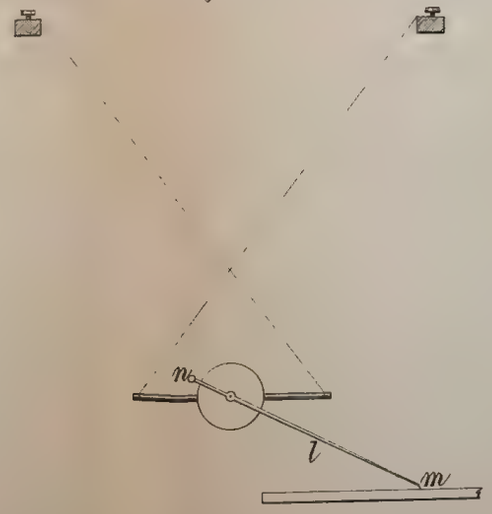

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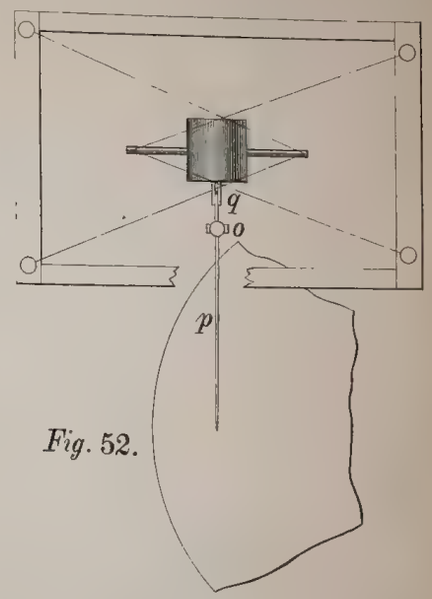

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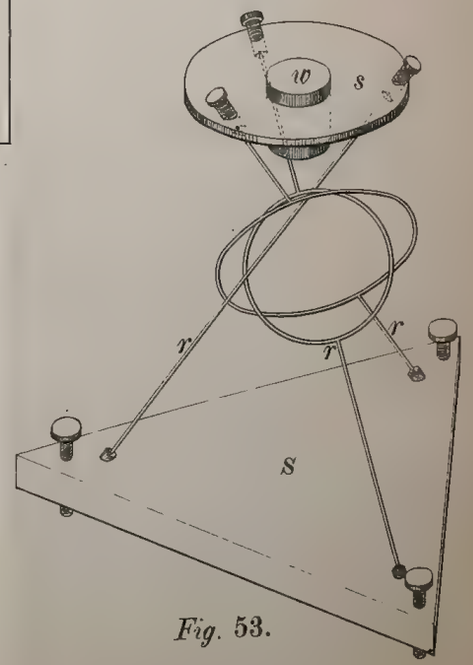

Fig. 53.

ABHANDLUNGEN

DES

TOKIO DAIGAKU.

(Universität zu Tokio.)

No. 10.

PHYTOCHEMISCHE NOTIZEN

UEBER EINIGE

JAPANISCHE PFLANZEN.

SMITHSONIAN INSTITUTION
JUN 16 1926
NATIONAL MUSEUM

VON

J. F. EYKMAN.

Professor für Chemie und Pharmacie an der medicinischen Facultät.

HERAUSGEGEBEN VOM TOKIO DAIGAKU.

TOKIO.

2543 (1883.)

SMITHSONIAN INSTITUTION
JUN 16 1926
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ABHANDLUNGEN

DES

TOKIO DAIGAKU.

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HERAUSGEGEBEN VOM TOKIO DAIGAKU.

TOKIO.

2543 (1883.)

EINLEITUNG.

Die Japanische Flora, so interessant in botanischer Hinsicht, bietet eine Reihe von Pflanzen dar, welche auch in chemischer Hinsicht, toxicologisch wie pharmacologisch, das höchste Interesse verdienen.

Nur eine kleine Anzahl ist bis jetzt Gegenstand solcher Forschungen gewesen, und daher liegt hier noch ein ziemlich unerschöpftes Feld zur Bearbeitung vor.

Die Wichtigkeit phytochemischer Untersuchungen von einheimischen Pflanzen erhellt leicht, wenn man die Schwierigkeiten ins Auge fasst, welche bei hiesigen forensischen Untersuchungen auftreten und eine Folge sind von der Unbekanntheit mit den giftigen Bestandteilen der einheimischen Flora. Wenn auch die üblichen Methoden zur Ausmittelung der Gifte es gestatten, unbekannte Gifte abzuscheiden und das physiologische Experiment an Tieren dann häufig über ihre Giftigkeit Auskunft geben kann, so ist es doch für ihre weitere Erkennung auf chemischem Wege erforderlich, dass man sowohl genauere Kenntnisse über diese Gifte selbst besitzt als auch solche andere nicht giftige Pflanzenbestandteilen kennt, welche zur Verwechslung mit bekannten Giften Anlass geben könnten.

Auch von medicinischem Standpunkte sind mehrere Pflanzen oder ihre Drogen wichtig, sei es dass sie wegen einer therapeutisch verwertbaren Wirkung einen Platz im Arzneischatz verdienen, sei es dass sie mehr locale Bedeutung besitzen, insofern sie als Ersatz von anerkannt wichtigen europäischen Pharmaca dienen können.

Schon früher hatte ich begonnen einzelne einheimische Pflanzen von obigem Standpunkte aus zu untersuchen, und ich habe diesen Plan wieder aufgenommen als mir mein Eintritt in die hiesige medicinische Facultat dazu weitere Gelegenheit bot. Es schien mir dabei zweckmässig, meine Aufmerksamkeit einstweilen auf die wichtigeren Bestandteile zu beschränken, um so eine grossere Zahl von Pflanzen oder Pflanzenteilen wenigstens vorlaufig zu erledigen. Meine Untersuchungen bieten daher weder ein abgeschlossenes Ganze noch machen sie Anspruch auf etwaigen Erschöpfung der einzelnen Gegenstande. Den Herren T. Shimoyama, K. Tamba und T. Niwa, die mir dabei abwechselnd, jeder wahrend eines Semesters, zur Seite standen bin ich für ihre Unterstutzung zu lebhaftem Dank verpflichtet. Denselben Herren verdanke ich auch sammtliche Angaben aus der mir nicht zuganglichen japanisch-chinesischen Litteratur.

Auch sei es mir hier gestattet, dankend die grosse Liberalität hervorzuheben, womit seitens des Tokio-Daigaku sowohl die oft grossen Quantitäten des zur Untersuchung dienenden Materials als das Laboratorium, auch während der Ferien, zu meiner Verfügung gestellt wurde. Die beigefügten Tafeln sind von Herrn K. Tsikasawa ausgeführt.

Leider stand mir über Phytochemie nur eine sehr beschränkte Litteratur zu Gebote und hoffe ich, auch da, wo ich vielleicht nicht genügend die Arbeiten Anderer über verwandte Gegenstände benutzte, nachsichtige Beurteilung zu finden.

Tokio-Universität. J. F. EYKMAN.

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I. ANDROMEDA JAPONICA THUNB.

Von den vielen in Japan und China einheimischen und zu der Gattung *Andromeda* gehoerenden Ericaceen ist die Andromeda Japonica eine hier allgemein als giftig bekannte Staude. Als solche findet sie sich schon in den ältesten Werken über Naturgeschichte Japan's und China's erwähnt.

Was sich in dieser Literatur über die Pflanze findet, lässt sich folgendermassen kurz zusammenfassen.

Die länglichen, bitter und zusammenziehend schmeckenden Blätter sind giftig und üben, von Pferden und Kühen gefressen, eine betäubende und giftige Wirkung aus. Daher die Namen: Basuiboku 馬酔木(1), Umakuwasu ウマクハズ(2), wie auch Shika kuwasu シカクハズ(3) und Sishi kuwasu シヽクハズ(4).

Ein Abzug der Blätter vertilgt Insecten und Würmer(5) und soll als Waschmittel bei Ulcerationen und Scabies und auch als Gegengift gegen Fugu(6) gebraucht werden; die zerstossenen Blätter können nach Sohki (Chin. Arzt) als Mittel gegen Schlangenbiss dienen, und der Geruch einer Abkochung der Blätter verursacht beim Menschen Kopfschmerz (7).

Die Pflanze wächst überall auf Bergen(8), ist immergrün und wird daher als Zierpflanze benutzt.

Eine Reihe von Namen sind in den verschiedenen Provinzen in Gebrauch.(9)

(1—3) Ba = Uma = Pferd, sui = betäubend, boku = Baum, kuwasu = nicht essen, Shika = Hirsch.

(4) Thunberg, Flora Japonica: „sis kwas, i. e. Leo non edat vel leoni non conducit edere: sis enim leonem significat. Item sishi gakure" (gakure = sich verstecken.)

(5) Honzokomoku keimo 本草綱目啓蒙

(6) Daher der Name Fugu Shiba (Fugu = Giftfisch, Shiba = Pflanze) 河豚柴

(7) Yudoku Somoku Susetsu 有毒草木圖說. Auch wird da erwähnt, dass bei Hirschen, welche die Blätter fressen, die Hörner plötzlich abfallen. In der Honzokomoku 本草綱目 von Lishishin 李時珍 wird noch angegeben, dass ein Abzug der Blätter das unreine Blut bei der Frau nach der Geburt abtreibt.

(8) Thunberg und Oldham fanden sie bei Nagasaki, Bürger in Homanduke, Savatier in Hakone und Sagami (Franchet und Savatier, Enumeratio plantarum). Nach Sohki wächst sie in China in den Wäldern von Kohto.

(9) In Honzokomoku keimo finden sich noch folgende Namen:

Yosebi ヨセビ
Yoshimi ヨシミ
Yoshimishiba ヨシミシバ
Yomeha ヨメハ
Dokushiba ドクシバ
Kusukui カスクイ
Onnasakamori ヲナサカモリ
Tenkishiba テンキシバ
Aseboshiba アセボシバ

Die am meisten üblichen sind: *Asebo* アセボ und *Basuiboku.*

E. Kämpfer in seinen *Amönitates exoticae* Fasc. V. p. 896. A° 1712 beschreibt diese Pflanze etwas ausführlicher unter den Namen Asjebo und Asjemi. In Thunberg's Flora Japonica p. 181 findet sich eine gute Beschreibung nebst einer Abbildung der Pflanze (1)

Soweit ich in Erfahrung habe bringen können, wurde diese Pflanze hier schon mehrfach zum Gegenstande von Untersuchungen gemacht, und es hat sich dabei herausgestellt, dass ihre Giftigkeit keinem Alkaloide zuzuschreiben sei, dass die Blätter giftiger sind als das Holz und dass das Gift nicht durch Bleiacetat gefällt wird, Diese Resultate wurden schon vor etwa sieben Jahren im hiesigen Laboratorium erhalten. Unabhängig davon beschäftigte ich mich kurze Zeit mit der Untersuchung des Holzes (Ende 1880-Anfang 1881) auf Wunsch des Herrn Nagayo Sensai, Chefs des Central-Gesundheitsamts. Es war ein Vergiftungsfall, der damals zu dieser Untersuchung Veranlassung gab. Wiewohl es mir leicht gelang, eine amorphe, fast farblose Substanz von heftig beizendem Geschmack abzuscheiden(2), so konnte ich doch, weil ich die Untersuchung unterbrechen musste, damals nicht nachweisen, in wieweit diese Substanz rein war, und in wieweit ihr als solcher die giftige Wirkung des Holzes zuzuschreiben war.

Yosebo ヨセボ
Gomajakishiba ゴマヤキシバ
Shiyari-shiyari シヤリシヤリ
Hassasagi ハササギ

Auch kommen in alten Liedern vor:

Asemi アセミ
Asemo アセモ
Asebi アセビ

Chinesische Namen sind,

Shinboku 枝木
Tin-shu-kwa 珍珠花 (tin = merkwürdig, shu = Kugel, kwa = Blume)
Bei-han-kwa 米飯花 (Bei han = gekochter Reis, kwa = Blume)

Der Name *Dodan*, von Franchet & Savatier u. A. erwähnt für A. Japonica, ist der des Enkyanthus Japonicus, wie mir Herr Prof. Ito Keisuke freundlichst mitteilte.

(1) Caulis arboreus, ramosus. Rami terni vel plures subumbellati, striato-angulati, glabri, purpurascentes, a casu foliorum nodulosi erecti, iterum ramulosi. Folia in ultimis ramulis frequentia, alterna, petiolata, obovato-lanceolata, acuta, inferne attenuata in petiolos a medio ad apicem crenata, patentissima vel reflexa, nervosa, glabra, bipollicaria. Petioli semiteretes, sulcati, rubri, lineam longi. Flores in apicibus ramulorum racemosi. Racemi alterni, laxi, rubri digitales. Pedicelli teretes, incrassati, erecti, lineam longi. Bracteae subulatae, sparsae sub et in pedicellis. Perianthium ante florescentiam 5-gonum, acutum, glabrum, altero latere rubrum altero viride, ad basin fere 5-partitum; laciniae lanceolatae, vix lineam longae. Corolla 1-petala, subcylindrica ore quinquefido, alba, calyce brevior, 5-striata. Filamenta 10, receptaculo inserta, linearia, all a. calyce triplo breviora. Antherae ovatae, erectae, intus gibbae, purpurascentes. Germen superum, 5-striatum, convexum, glabrum. Stylus filiformis, viridis, brevissimus. Stygma simplex, obtusum viride purpureum. Capsula ovato-globosa, 5 sulca angulis obtusis, glabra, 5 valvis, 5 locularis. Semina plurima, minuta.

(2) Sie wurde erhalten aus den mit Wasser oder verdünntem Weingeist dargestellten Extrakten durch wiederholte Ausziehung mit starkem Alkohol und Versetzen der alkoholischen concentrirten Lösung mit Aether. Die alkoholhaltige ätherische Lösung hinterliess beim Verdunsten einen amorphen, in Wasser schwierig, in Alkohol und Essigsäure leicht löslichen Rückstand.

Erst im Frühjahr 1882 konnte ich diese Untersuchung mit grösseren Quantitäten Materials (Blätter) wieder aufnehmen.

Zur Darstellung des Giftes wurden ziemlich grosse Quantitäten der frischen Blätter mit Wasser infundirt und das erhaltene Infus auf dem Dampfbade zur dünnen Sirupconsistenz eingedampft und d nach filtrirt. Zuerst wurde etwa ein halbes Liter dieses Infuses wiederholt mit officinellem Aether ausgeschüttelt; der ätherische Rückstand nach dem Abdestilliren des Aethers löste sich nur zum Teil in Chloroform auf, und der Chloroform-Auszug hinterliess einen fast farblosen Rückstand, welcher sich durch das physiologische Experiment auf Kaninchen heftig giftig erwies(*). Eine andere Probe des Infuses mit Chloroform geschüttelt zeigte, dass dieses Menstruum das Gift bei weitem reiner aufnimmt, als Aether(†), weshalb ich zum Ausschütteln der übrigen, grösseren Mengen des Infuses Chloroform benutzte.

Die durch Destillation concentrirte Chloroformlösung, welche grünlich gefärbt war, wurde mit soviel Petroleumäther versetzt, dass keine Ausscheidung mehr stattfand(‡). Dieselbe war nur wenig gefärbt und amorph; sie wurde in alkoholhaltigem (käuflich officinellem) Aether aufgenommen und diese Lösung wiederholt mit Wasser ausgeschüttelt. Die wässerigen Schichten wurden getrennt und in flachen Schalen bei gelinder Wärme eingetrocknet. Sie schieden dabei eine gelbe, ölartige Substanz ab, welche bei weiterem Eintrocknen in dünnen Schichten glasklare, farblose oder schwach gelblich gefärbte Rückstände hinterliess, woran nicht die geringste Neigung zur Krystallisation zu erkennen war. Auch durch partielle Fällung der ätherischen oder chloroformösen Lösung mittelst Petroleumäther erhielt ich nur amorphe Fällungen. Die meist farblosen Anteile wurden gesondert aufbewahrt. Der Rest, sowie die in dem Aether etc. zurückgebliebenen Portionen, welche nach dem Abdestilliren der Lösungsmittel zurückgewonnen wurden, bildeten eine gelbbräunliche, amorphe Masse, welche in wässeriger Lösung auf Lakmus deutlich sauer reagirte. Weil die reineren

(*) Bei der häufig wiederholten Ausschüttelung mit Aether schieden sich aus dem Infus Krystalle ab, welche gesammelt und abgewaschen fast völlig weiss waren und bei Verbrennung bedeutende Mengen kohlensauren Kalk haltige Asche zurückliessen, wonach es scheint, dass in den Blättern ein krystallisirendes Kalksalz vorhanden ist. Bei der weiteren Untersuchung habe ich dies aber nicht weiter verfolgt. Auch wurde in den Blättern gefunden:

66.7 % Wasser,
1.33 % in Petroleumäther,
7.86 % in Alkohol lösliches Extrakt und
2.38 % viel Calciumcarbonat haltige Asche.

(†) Aether nimmt ausserdem beträchtliche Mengen anderer Substanzen auf, welche mit Bleiacetat einen starken gelben Niederschlag, mit Eisenchlorid Blaufärbung erzeugen.

(‡) Das wässerige sirupöse Infus (mehrere Liter betragend) wurde in Portionen mit etwa 2-3 Liter Chloroform ausgeschüttelt, dann das Chloroform abgehoben und abdestillirt und oft zu erneuten Ausschüttelungen verwendet. Etwa 100 gr. in Chloroform lösliche Substanz von schwach grünlichgelber Farbe wurden auf diese Weise erhalten. Die Ausfällung mit Petroleumäther hatte den Zweck, die völlige Verjagung des Chloroforms durch längere Erwärmung zu umgehen und eventuell anwesende in Petroleumäther leicht lösliche Substanzen zu entfernen. Durch Destillation der chloroformhaltigen Petroleumätherlösung wurde der gelöste Anteil zurückgewonnen und bei späteren Reinigungen verwendet.

Anteile keine oder nur eine weinrothe Färbung mit Lakmus erzeugten, schien eine sauerreagirende Substanz beigemischt. Ich behandelte darum diese Quantität wie folgt. Sie wurde, in Chloroform gelöst, mehrere Tage mit etwas Bleihydroxyd unter öfterm Umschütteln stehen gelassen. Es bildete sich ein bräunlich-gelber Bodensatz, während bedeutende Mengen Blei in Lösung übergingen. Von der filtrirten Lösung wurde das Chloroform abdestillirt und über den Rückstand schwach übererhitzter Wasserdampf geleitet(*) Was in der Retorte zurückblieb, war eine ölige Flüssigkeit und eine wässerige. Die letztere enthielt bedeutende Mengen Blei, die ölige Flüssigkeit wurde nach dem Erkalten gummiähnlich fest. Sie wurde von der wässerigen Flüssigkeit getrennt und mit alkoholhaltigem (käuflich officinellem) Aether behandelt. Hierin löste sie sich zum grossen Teil, indem eine weissliche Bleiverbindung ungelöst zurückblieb, welche daher wohl in Chloroform, nicht aber in Aether löslich war. Die ätherische Lösung enthielt nur Spuren Blei, welche leicht durch einmalige Ausschüttelung mit ein wenig Wasser und Durchleiten von etwas H_2S entfernt werden konnten. Die ätherische Lösung mit etwas Weingeist versetzt, lieferte, mit Wasser ausgeschüttelt, Auszüge, welche bei der Eindunstung sich wie früher verhielten und zu spröden, glasartigen, amorphen Massen eintrockneten. Die am meisten farblosen Anteile wurden wieder gesondert aufgehoben und stimmten in ihren Eigenschaften mit den früher erhaltenen Quantitäten überein.

Die in Aether ungelöst gebliebene Bleiverbindung wurde mit Chloroform übergossen der Einwirkung von H_2S ausgesetzt. Das bleifreie Filtrat lieferte beim Verdampfen ebenfalls einen amorphen, gelben Rückstand.

Die etwas mehr gefärbten Rückstände der wässerigen Ausschüttelungen und die in den ätherischen Menstrua gelöst zurückgebliebenen Quantitäten wurden nochmals in Chloroform gelöst, diese Lösung wurde dann mit Wasser und soviel K_2CO_3-lösung geschüttelt, dass die Reaction sehr schwach alkalisch war. Aufbrausen wurde dabei nicht beobachtet. Die wässerigen und chloroformösen Schichten, welche beide bräunlich gefärbt waren, wurden getrennt und die chloroformöse Lösung mit etwas Tierkohle geschüttelt, wodurch sie sich klar filtriren liess. Das Filtrat wurde partiell mit Petroleumäther gefällt und die weniger gefärbten Anteile gesondert getrocknet und mit *absolutem* Aether gekocht. Der filtrirte Auszug liess beim Eindunsten einen schwach gelblichen Rückstand, welcher

(*) Es hatte dies den Zweck, leicht flüchtige Körper zu entfernen. Das wässerige Destillat, worauf eine sehr geringe Menge eines fettigen Körpers zich zeigte, wurde mit Aether ausgeschüttelt. Nach freiwilliger Verdunstung desselben blieb aber nur eine sehr geringe Menge Rückstand, welcher, in Wasser verteilt und einem Kaninchen eingespritzt, keine deutlichen Vergiftungssymptome zeigte. Mit concentrirter Salzsäure färbte es sich röthlich. Beim Ueberleiten des Wasserdampfes entwickelte sich ein eigentümlicher, nicht sehr unangenehmer, aber betäubender Geruch. Es kommt mir wahrscheinlich vor, dass schon beim Ueberleiten von schwach übererhitztem Wasserdampfe Zersetzung eintritt unter Bildung eines betäubend riechenden Körpers, weil auch bei mehrstündigem Ueberleiten des Wasserdampfes dieser Geruch in gleich intensiver Weise auftritt und das Nicht- Auftreten von Vergiftungssymptomen sowie die röthliche Färbung mit H Cl dagegen spricht, dass die Substanz unverändert überdestillire.

in wasseriger Lösung völlig neutral reagirte. Mit Salzsäure auf Pt-Blech erhitzt, entstand Dunkelblaufärbung, nachher intensive Purpurfärbung, und unter Bildung weisser Dämpfe blieben höchst geringe Spuren Asche zurück. Mit conc. Salzsäure übergossen entstand nach einiger Zeit Dunkelblaufärbung.

Die wässerige $K_2 CO_3$ haltige Lösung wurde mit verdünnter Schwefelsäure angesäuert und mit Aether ausgeschüttelt; der abgehobene Aether, mit etwas Wasser gewaschen und der freiwilligen Verdunstung überlassen, hinterliess wieder einen amorphen (schwefelsäure-freien) Rückstand, der stark saure Reaction zeigte und mit Salzsäure ebenfalls blau wurde. Hiernach scheint das reine Gift entweder durch Oxydation oder unter dem Einflusse schwacher Basen als Zersetzungsprodukt einen sauerreagirenden Körper zu bilden; vielleicht findet dies auch schon durch Bleihydroxyd statt; dies würde erklären, wie beim Schütteln der chloroformösen Lösung des Giftes mit $Pb (O H)^2$ während mehrerer Tage sich immer mehr von einer Bleiverbindung in dem Chloroform löst. Weil auch verdünnte Säuren, sogar Oxalsäure, beim Erwärmen das Gift sichtbar zersetzen, scheint mir bei der Darstellung und Reinigung jede Anwendung von chemisch wirkenden Agentien unstatthaft und nur diejenige Methode zu empfehlen, welche, wenn auch mit Verlust, die Erhaltung eines reinen Präparates auf mehr mechanischem Wege ermöglicht.

Es wurden deshalb die erhaltenen reineren Portionen, nach dem Trocknen zu Pulver zerrieben, wiederholt mit Petroleumäther und Benzol ausgezogen und nochmals in alkoholhaltigem Aether gelöst. Nach dem Ausschütteln mit Wasser wurden die resultirenden verdünnt alkoholischen Lösungen wieder bei mässiger Wärme eingetrocknet und die spröde glasartige Substanz gepulvert.

Sie war schwierig in kaltem, besser in heissem Wasser und leicht in Weingeist, Eisessig, Amylalkohol, Chloroform und alkoholhaltigem (käuflich officinellem) Aether löslich. Petroleumäther und Benzol lösten dagegen sehr wenig. Die wässerige Lösung wurde weder gefällt noch verändert durch Eisenchlorid und Silbernitrat und hatte einen bitteren, stark beizenden Geschmack.

Beim Verbrennen schmilzt sie, verbreitet scharfe Dämpfe und hinterlässt keine Spur Asche. Mit concentrirter HCl übergossen, zeigt sie, auf weisser Unterlage betrachtet, nach einiger Zeit eine schöne reine Blaufärbung; unter Bildung einer bläulichgrauen Trübung wird die Lösung allmählich mehr röthlich und zuletzt missfarbig.(*)

Wird die blaue Lösung auf dem Wasserbade erwärmt, so entsteht an der Peripherie eine schöne violettlich rothe Farbe.

In alkoholischer Lösung mit concentrirter HCl erwärmt, entsteht eine prachtvolle dunkle Purpurviolettfärbung. Mit verdünnter Salzsäure oder Schwefelsäure erhitzt, trübte sich die wässerige Lösung und färbte sich

(*) Neben dem stechenden Geruch der Salzsäuredämpfe liess sich ein eigenthümlicher, etwa an Spiräa ulmaria erinnernder Geruch wahrnehmen. Auch beim Kochen der Substanz mit verdünnten Mineralsäuren war ebenfalls ein besonderer, etwas mehr rhamnusähnlicher Geruch zu erkennen.

schön (carthaminähnlich) roth unter Ausscheidung eines bräunlichen harzigen Stoffes. Concentrirte Schwefelsäure löste es mit bräunlichrother Farbe, die beim Stehen an der Luft schöner, rosaroth wurde. Durch die Cyanprobe konnte kein Stickstoff nachgewiesen werden.

Als dosis letalis für Kaninchen wurden pro K° Körpergewicht etwa 3 mgr. bei subcutaner Injection gefunden.

Gewicht Kaninchen p. K°	Eingespritzte Quantität der Substanz	Dosis berechnet auf 1 K° Körpergewicht	Resultat
3.24	9.5	2.9	Tod in $1^3/_4$ h.
2.8	5.5	2.	Hergestellt nach einigen Stunden
1.35	4.5	3.3	Tod in 1 h.
1.28	3.5	2.8	Tod in 3 h.
1.25	2.5	2.	Hergestellt nach einigen Stunden

Die äusseren Symptome, welche ich bei Kaninchen wahrnahm, sind etwa folgende: bei ungefähr letaler Dosis fängt das Kaninchen nach 15-20 Minuten an, unter Hervorbringung klagender oder schreiender Laute zurückziehende Bewegungen mit dem Kopfe zu machen. Diese werden allmählich stärker, wobei dann die Bewegung des Kopfes nach vorwärts gepaart geht mit weiter Oeffnung des Maules und der Nasenlöcher und schnalzenden Lauten. Oefters wurde Defäcation oder Harnlassen beobachtet. Die Körperwärme nimmt deutlich ab, und das Tier kann sich weniger gut bewegen. Es tritt Paralysis der Extremitäten auf, die Mucosa des Mundes und der Nasenhöhlen sind sehr anämisch, und unter Ausfluss von Schleim tritt nach einigen Convulsionen, anscheinend durch Erstickung, der Tod ein.

Hunde beginnen bald nach der Darreichung des Giftes zu erbrechen.(†)

In Anklang mit dem japanischen Namen *Asebodoku* = *Asebo-gift* habe ich für die Substanz den Namen *Asebotoxin* gewählt.

Zwei Elementaranalysen lieferten folgende Zahlen:

I. 0.2732 gr. bei 110°—115° getrocknet gaben 0.2631 gr. Trockensubstanz und nach Verbrennung 0.5815 gr. CO_2 und 0.1983 gr. H_2O

II. 0.3288 gr. bei 110°—115° getrocknet lieferten 0.3181 gr. Trockensubstanz und 0.7073 gr. CO_2 und 0.2078 gr. H_2O.

Zur weiteren Bestätigung der Reinheit der Substanz wurde das noch übrige Pulver mit absolutem Aether (über Na destillirt) übergossen und in

(†) Die Erscheinungen sind denjenigen analog, welche ein wässeriges Infus der Blätter zeigt. 1 Cm^3 eines solchen Infuses, correspondirend mit etwa 200 mgr. der jungen Blätter, tödtete ein Kaninchen von etwa 1·14 K° Körpergewicht und stimmt deshalb in toxischer Wirkung mit ungefähr 3—4 mgr. des Giftes überein.

zwei Portionen getrennt. Es zeigte sich dabei, dass das Asebotoxin in diesem Menstruum schwieriger als in nicht- absolutem Aether löslich ist. Sowohl von dem in Aether gelösten als von dem darin ungelöst gebliebenen Teil wurden nach dem Trocknen bei 110°—115° Elementaranalysen ausgeführt. Der in Aether gelöste Teil löste sich nach dem Eintrocknen ebenso in absolutem Aether schwierig auf.

Gefunden wurde:

III. *In Aether ungelöster Anteil*
0.3575 gr. lieferten 0.7929 gr. CO_2 und 0.2368 gr. H_2O

IV. *In Aether gelöster Teil*
0.3898 gr. gaben 0.8651 gr. CO_2 und 0.2610 gr. H_2O

Also in Procenten:

	I	II	III	IV	Mittel
C = 12	60.28	60.64	60.49	60.52	60.48
H = 1	7.53	7.29	7.36	7.44	7.405
O = 16	32.19	32.17	32.15	32.04	32.115

Die Uebereinstimmung der Zahlen III und IV, auch in Vergleich mit I und II, dürfte noch für die Reinheit des Asebotoxins sprechen. Es blieb mir nun noch eine kleine Quantität von dem bei der partiellen Lösung in Aether zurückgebliebenen Anteile, um einige weitere Reactionen anzustellen.

Die wässerige Lösung reducirte beim Kochen alkalische Kupferlösung(*) und wurde nicht von Bleiacetat, Goldchlorid, Kupfersulfat, Quecksilberchlorid und Eisenchlorid verändert noch gefällt. Durch Bleisubacetat (Bleiacetat + NH_3) entstand eine flockige Trübung. Die Lösung in Alkohol reagirte auf Lakmus neutral, die warm bereitete wässerige Lösung veränderte blaue Lakmustinktur nicht oder färbte sie kaum röthlich violett. Auch die Lösung in Chloroform, mehrmals auf Lakmuspapier eingetrocknet, veränderte dieses nicht.

Ein Teil des wässerigen Infuses, woraus durch Chloroform das *Asebotoxin* erhalten war, wurde wiederholt mit officinellem Aether ausgeschüttelt. Bei dem Abdestilliren des Aethers blieb, namentlich bei den letzten Anteilen mehr farblos, eine krystallinische Masse zurück, welche mit Bleiacetat einen chromatgelben, mit Quecksilberchlorid einen weissen und mit ammoniakaler Silberlösung einen starken schwarzen Niederschlag erzeugte: Eisenchlorid gab Fällung und tiefe Grünblaufärbung. Die Rückstände reagirten sauer und wurden mit Chloroform zur Entfernung des noch gelösten Asebotoxins ausge-

(*) Eine gleiche Quantität dieser wässerigen Lösung, mit verdünnter Schwefelsäure gekocht, lieferte nach dem Abfiltriren des braunen harzigen Zersetzungsproduktes und Neutralisation mit Natronlauge eine anscheinend wenigstens gleichstarke Reduction. Da das abgeschiedene, harzige, in Weingeist und Aether leicht lösliche Zersetzungsprodukt keine sichtbare Reduction mit alkalischer Kupferlösung zeigte, scheint die gelöst bleibende Substanz eine stärkere Reductionsfähigkeit als das Asebotoxin zu besitzen.

zogen, dann mit Wasser gekocht und die Lösung mit essigsaurem Blei gefällt. Nach dem Abfiltriren des orangegelben Präcipitates wurde aus dem Filtrate das Blei entfernt. Nach Eindunsten der Flüssigkeit wurden gelblich gefärbte Krystalle erhalten, die in grösseren Quantitäten aus dem Rest des wässerigen Infuses gewonnen wurden. Dieser wurde warm mit Bleiacetat gefällt, aus dem Filtrate das Blei grossenteils durch verdünnte Schwefelsäure und zuletzt durch H_2S gefällt. Nach Eindampfen des Filtrates und längerem Stehen schied sich eine Krystallmasse ab, welche durch Umkrystallisation aus Wasser und verdünntem Alkohol etwas gereinigt wurde. Durch wiederholte Umkrystallisation aus Wasser und verdünntem Alkohol konnte ich sie nicht völlig farblos erhalten. Dies gelang aber folgendermassen: ein Teil wurde in 20 Teilen absolutem Weingeist gelöst, wenn nöthig filtrirt und etwa 200 Teile absoluten Aethers zugesetzt. Durch Schütteln dieser Lösung mit Tierkohle wurde die Flüssigkeit völlig farblos und klar. Nach dem Abfiltriren wurden der Lösung etwa 100 Teile Wasser zugesetzt und dann der Aether abdestillirt. Die zurückbleibende verdünnt alkoholische Lösung lieferte nach dem Abkühlen ganz farblose, glänzende, völlig gleichförmige Krystallnadeln. Sie wurden bei gewöhnlicher Temperatur getrocknet und zur Entfernung von eventuell anhängenden Spuren Asebogenin mit Aether abgewaschen und nochmals aus Wasser umkrystallisirt. Diese Substanz, *Asebotin*, hatte folgende Eigenschaften:

Farblose und glänzende Nadeln, welche sehr wenig in kaltem, gut aber in kochendem Wasser löslich sind; Petroleumäther, Benzol, Chloroform und absoluter Aether lösen es nicht oder sehr wenig.(*) Die Lösung in Wasser hat einen rein bitterlichen Geschmack. Alkohol, auch absoluter, und Eisessig lösen es sehr leicht. Es reagirt neutral, und seine wässerige Lösung wird von den gewöhnlichen Metallsalzen, auch Bleiacetat, weder verändert noch gefällt. Mit Bleisubacetat (Bleiacetat + NH_3) aber giebt es eine starke weisse Fällung. Für den Schmelzpunkt fand ich 147°5 (uncorr.), für das spec. Gew. 1.356 bei 15°. In kleinen Dosen, etwa 5 mgr., in etwas warmer Lösung Kaninchen eingespritzt, zeigte es keine abnormen Erscheinungen.

In verdünnten Alkalien, etwas weniger leicht in Ammoniak, löst es sich in grossen Mengen auf zu einer farblosen Lösung, worin verdünnte Säuren wieder einen nach einiger Zeit krystallisirenden Niederschlag bewirken(†) An der Luft färbt sich die alkalische Lösung nach längerer Zeit braun. Mit

(*) Einige Löslichkeitsbestimmungen bei gewöhnlicher Temperatur führten zu etwa folgenden Verhältnissen.

Wasser	1 : 2000 à 2500
absoluter Aether	1 : 6000 à 6600
Chloroform	1 : 25000

(†) 0.4758 Gr. des *Asebotins* lösten sich leicht auf in einer verdünnten Kalilösung, welche 0.105 gr. reine KOH enthielt. Brom verursacht in dieser alkalischen Lösung eine hellgelbe Abscheidung, durch Ueberschuss übergehend in eine in Chloroform und Aether sehr lösliche und bei Verdampfung sich amorph abscheidende Substanz, welche allmählich eine hochrothe Farbe annimmt.

Salpetersäure erwärmt und eingedampft blieb ein in Wasser mit gelber Farbe löslicher Rückstand, der deutliche Quantitäten Oxalsäure enthielt.

Alkalische Kupferlösung wird in der Kochhitze durch das Asebotin nicht reducirt, nach vorheriger Erhitzung mit verdünnten Mineralsäuren findet aber starke Reduction statt; ammoniakale Silberlösung wird nicht reducirt.

In einer feuchten Atmosphäre von Ammoniak mehrere Tage unter eine Glocke gestellt färben sich die mit Wasser befeuchteten Krystalle röthlich braun.

Bei 100° getrocknet verloren sie kein Krystallwasser.

Elementar-Analysen:

I 0.3130 gr., bei 100° getrocknet, lieferten 0.1574 gr. H_2O und 0.6548 gr. CO_2

II 0.3533 gr., bei 100° getrocknet, lieferten 0.1775 gr. H_2O und 0.7383 gr. CO_2

oder in Procenten:

	I	II	Mittel	Berechnet auf $C_{24}\ H_{28}\ O_{12}$(*)
C = 12	57.05	56.99	57.	56.7
H = 1	5.59	5.58	5.6	5.5
O = 16	37.36	37.43	37.4	37.8

Kocht man das *Asebotin* mit verdünnten Mineralsäuren, so wird die Flüssigkeit bald trübe und scheidet sich eine krystallinische Substanz, *Asebogenin*, aus, indem die Flüssigkeit nach Erkältung und Filtration starke Reaction gegenüber alkalischer Kupferlösung zeigt.

1.427 Gr. *Asebotin* mit etwa 30 Cm^3 verdünnter Schwefelsäure (c^a 1:7) gekocht, lieferten, nach dem Abwaschen und Trocknen bei 100°, 0.941 Gr. = 65.9% in absolutem Aether leicht lösliches *Asebogenin*. Filtrat und Waschwasser wurden mit Baryumcarbonat unter Erwärmung behandelt, nach Filtration die Flüssigkeit zu einem kleinen Volum eingeengt und mit starkem Alkohol versetzt. Das Filtrat lieferte nach Verdunstung eine bedeutende Quantität eines amorphen, hellgelblich gefärbten, ganz in ihrem äusseren Ansehen Glucose- ähnlichen Substanz, die stark reducirend auf alkalische Kupferlösung wirkte.

0,4462 gr. *Asebotin* lieferten, mit etwas grösserer Quantität verdünnter Schwefelsäure (1:15) gekocht, bis sich das *Asebogenin* wieder abgeschieden hatte, und nachher noch mehrere Stunden auf dem Wasserbade erhitzt, 0.280 gr. = 62.7%, ebenfalls in absolutem Aether ganz und leicht lösliches *Asebogenin*. Das Filtrat wurde unter Erwärmung mit $Na_2\ CO_3$ fast vollkommen neutralisirt, die Flüssigkeit auf dem Wasserbade eingeengt und auf ein bestimmtes Volum verdünnt; sie zeigte bei der Titration mit einer alkalischen Kupfer-

(*) Wegen der vollkommnen Uebereinstimmung der Resultate dieser beiden Analysen wurde eine dritte nicht ausgeführt. Wenn auch mehrere empirische Formeln sich aus diesen Zahlen berechnen lassen, welche mehr oder weniger annähernd stimmen, ist nur die obige angeführt, weil sie am besten mit den Spaltungsprodukten durch Säuren übereinstimmt.

lösung einen Reductionswerth von 36.2 Glucose. Weil ich keine grössere Quantität des Asebotins mehr besass, musste ich die weitere quantitative Bestimmung der Spaltungsprodukte unterlassen.

Das Asebogenin, welches bei andauerndem Kochen mit den verdünnten Mineralsäuren sich grünlich gelb abschied, wurde leicht völlig farblos erhalten durch mehrmalige Lösung in starkem Alkohol und Fällung mit der etwa zehnfachen Menge Wasser.

Eigenschaften des Asebogenins.

Farblose, sehr feine Krystallnadeln, welche in kaltem, wie auch in kochendem Wasser sehr wenig löslich sind. Auch in Chloroform ist es unlöslich, dagegen löst es sich in Alkohol und Aether, auch absolutem, wie in Essigsäure, sehr leicht auf.

Es ist geruchlos, reagirt neutral und giebt mit Bleisubacetat (NH_3 + Bleiacetat) starke weisse Fällung. Als Schmelzpunkt fand ich 162° — 163° (uncorr.) In Alkalien ist es leicht löslich.

0.2958 gr., bei 100° C getrocknet, lieferten 0.1439 gr. H_2O und 0.6764 gr. CO_2 oder in Procenten:

		Berechnet auf $C_{18}H_{18}O_7$
C = 12	62.37	62.43
H = 1	5.40	5.20
O = 16	32.23	32.37

Eine zweite Analyse konnte ich wegen Mangels an Substanz nicht ausführen.

Durch seine Zusammensetzung, Schmelzpunkt etc. und namentlich schon durch seine sehr geringe Löslichkeit in kochendem Wasser und leichte Löslichkeit in absolutem Aether unterscheidet sich das Asebogenin scharf von dem Asebotin.

Die Spaltung dieses letzteren konnte durch die Gleichung:

$$C_{24}H_{28}O_{12} + H_2O = C_{18}H_{18}O_7 + C_6H_{12}O_6$$

ausgedrückt werden. Nach dieser hätte ich erhalten müssen 68.1% Asebogenin und 35.4% Glucose, während ich fand: 1° Mal 65.9%, 2° Mal 62.7% Asebogenin und 36.2% Glucose. Das Deficit an Asebogenin, welches da am grössten war, wo die grösste Quantität schwefelsäurehaltigen Wassers bei der Spaltung gebraucht wurde, kann auf Rechnung der geringen Löslichkeit des Asebogenins in kaltem Wasser gebracht werden.

Bei dem Vergleich der Eigenschaften des Asebotins mit anderen Bitterstoffglucosiden, kommt Phloridzin in vielen Hinsichten damit überein, unterscheidet sich aber schon u. a. durch seine Phloridzein- Ammoniak- Reaction, wovon ich mich durch Vergleich mit zwei Proben Phloridzin überzeugte.

Mehr weicht es in seinen Eigenschaften von dem in Ericaceen aufgefundenen Arbutin(*) ab, welches aber nur um die Elemente des Wassers vom Asebotin zu differiren scheint.

(*) Ein hier vorräthiges Muster Arbutin wurde in einer feuchten NH_3—Atmosphäre blau gefärbt, was ich in der mir zugänglichen Litteratur nicht erwähnt fand.

$$2\ C_{12}\ H_{16}\ O_7 - 2\ H_2O = C_{24}\ H_{28}\ O_{12}$$
Arbutin Asebotin.

Auch ist das *Asebogenin* verschieden von dem *Hydrokinon*, welches *Hesse* als Spaltungsprodukt des *Arbutins* fand.

Ebenso kann das *Asebotin* nicht mit dem *Methylarbutin* (Schmpt. 168°-169°) identisch sein wegen seines niedrigeren Schmelzpunktes, der geringen Löslichkeit in kaltem Wasser und der abweichenden Eigenschaften des *Asebogenins* (Schpt. 162°-163°) von dem *Methylhydrokinon* (Schpt. 53°)(*) Möglich aber ist es, dass bei der Spaltung des *Asebotins* etwas Hydrokinon sich bildet nach der Gleichung

$$C_{24}\ H_{28}\ O_{12} + 4\ H_2O = 2\ C_6\ H_{12}\ O_6 + 2\ C_6\ H_6\ O_2$$

oder Chinhydron nach der Gleichung

$$C_{18}\ H_{18}\ O_7 = C_6\ H_6\ O_2 + C_{12}\ H_{10}\ O_4 + H_2\ O,$$

worauf vielleicht die grünliche Färbung des *Asebogenins* hinweisen würde.

Ein Teil des aus dem wässerigen Infuse durch Bleiacetat gefällten Niederschlags wurde, in Wasser verteilt, mit H_2S zerlegt und heiss filtrirt. Das Filtrat wurde eingeengt und die braune Extraktmasse mit starkem Alkohol ausgezogen. Der Auszug wurde mit Aether versetzt, wobei sich eine braune harzige Substanz ausschied. Die Lösung, die braun gefärbt war, lieferte nach der Destillation einen braunen Rückstand, der mit essigsaurem Blei einen orangegelben Niederschlag, mit Eisenchlorid dunkle Grünblaufärbung gab und deutlich sauer reagirte.

Ich extrahirte diese braune Substanz dann mit Wasser, schüttelte die Lösung wiederholt mit Aether aus und behandelte den Rückstand nach dem Abdestilliren des Aethers mit Wasser und kohlensaurem Calcium, concentrirte das Filtrat und fällte mit starkem Alkohol. Es entstand ein weisser Niederschlag, welcher abfiltrirt, ausgewaschen und in Wasser gelöst wurde. Die mit Salzsäure versetzte Lösung wurde wieder mit Aether ausgeschüttelt, welcher dann einen Rückstand zurückliess, welcher zum Teil krystallisirte und nach Reinigung durch Umkrystallisation aus Wasser zum Teil farblose, scharfe Krystalle bildete. Dieselben hatten einen kühlenden säuerlichen Geschmack und gaben mit $Fe_2\ Cl_6$ dunkel grünlich blaue Färbung ohne Bildung eines Niederschlags. Diese blaue Lösung wurde auf Zusatz von Alkali intensiv violettroth, Bleiacetat gab starken weissen Niederschlag, in Essigsäure löslich. In saurer erwärmter

(*) Das von *A. Michael* synthetisch erhaltene *Methylarbutin* aus Acetochlorhydrose und dem Kaliumsalze des Methylhydrokinons wird (Berl. Ber. *14*. 2099) als leicht löslich in Wasser und Alkohol beschrieben.

Für die bei 120° entwässerte (wobei sie $^1/_2$ Mol. H_2O verlor) Substanz fand *A. Michael*, der Theorie entsprechend, im Mittel 54.3% C und 6.6% H., während ich für das lufttrockne *Asebotin* 57% C und 5.6% H. fand, Zahlen, welche zu viel von einander differiren, um eine Identität beider Körper wahrscheinlich zu machen.

Weil das synthetisch erhaltene *Methylarbutin* mit $Fe_2\ Cl_6$ nicht blau wird, ist A. Michael der Ansicht, dass diese Arbutin-Reaction dem Hydrokinonglucoside eigen ist. Da das Asebotin diese Blaufärbung nicht zeigt, würde eine Identität mit dem Arbutin (Hydrokinon-Glucosid) auch hiedurch ausgeschlossen sein.

Lösung entfärbt sie schnell $KMnO_4$ und CrO_3, beide unter CO_2 Entwickelung. Sie reagirte in wässeriger Lösung stark sauer und war in Wasser gut, in Aether ziemlich, in Alkohol leicht, in Chloroform nicht löslich. Alkalische Kupferlösung wurde nicht, ammoniakale Siberlösung stark reducirt. Der Schmelzpunkt (etwa 160°—170°) war schwierig zu bestimmen, weil sich dabei Gasbläschen entwickelten. Beim Erhitzen zwischen zwei Uhrgläsern bildete sich ein krystallinisches Sublimat, das sich Eisenchlorid gegenüber ganz wie die Säure verhielt. Ob diese Substanz als solche vorkommt oder durch die Einwirkung der Salzsäure als Zersetzungsprodukt entstand, muss ist unentschieden lassen. Ich erhielt sie in zu kleiner Quantität, um sie noch weiter zu untersuchen; vielleicht ist sie aus einem durch Erwärmen mit HCl spaltbaren, ätherischen Derivat einer (protocatechusäureähnlichen) Säure entstanden (*)

Die harzige, sowie die gelbe, mit Bleiacetat orangegelben Niederschlag gebende Substanz wurden aus einer Portion getrockneter Blätter in grossen Quantitäten erhalten. Die grob gepulverten Blätter wurden mit Weingeist percolirt, der Auszug durch Destillation so weit concentrirt, dass sich eine grüne, fettige Substanz abschied, dann colirt und bis zur Extraktconsistenz eingeengt. Das Extrakt wurde mit sehr starkem Alkohol behandelt und dann etwa das doppelte Volum Aether zugesetzt; dadurch schied sich eine rothbraune, dicke, sirupöse Masse ab, welche gesondert wurde (siehe unten); von der Lösung wurde der Aether und Alkohol durch eine geeignete Destillation zurückgewonnen. Als Rückstand blieb dann eine rothbraune, sirupöse Masse, woraus sich allmählich eine grosse Menge eines orangegelben Bodensatzes abschied. Dieser wurde von dem mehr flüssigen Teil getrennt und liess nach der partiellen Ausziehung mit absolutem und verdünntem Weingeist eine bedeutende Quantität eines citronengelben Pulvers zurück. Durch wiederholte Reinigung und partielle Lösung oder Umkrystallisation mittelst verdünnten Alkohols konnte ich diese Substanz in zwei Teile von verschiedener Zusammensetzung trennen. Etwa 15 gr. eines schon gelben Pulvers, aus verdünntem, kochendem Alkohol in feinen Nadeln krystallisirend, gab, nach dem Trocknen bei 120°—125° C. analysirt, folgende Zahlen:

I 0.4558 gr. lieferten 0.1801 gr. H_2O und 0.9148 gr. CO_2
II 0.4469 „ „ 0.1721 „ „ „ 0.8951 „ „
III 0.3997 „ „ 0.1566 „ „ „ 0.8020 „ „

oder in Procenten:

	I	II	III	Mittel
C = 12	54.73	54.6	54.7	54.7
H = 1	4.38	4.28	4.35	4.34
O = 16	40.89	41.12	40.95	40.96

(*) Möglich auch ist es, dass Chinasäure, welche in anderen Ericaceen gefunden wurde, vorhanden ist. Ein vorläufiger Versuch, durch Oxydation des alkohol-ätherischen Extraktes mit MnO_2 und verd. H_2SO_4, Chinon zu erkennen, hatte keinen Erfolg. Es entwickelte sich viel CO_2 und auch Ameisensäure, ein Chinongeruch war jedoch nicht deutlich bemerkbar.

Eine andere Quantität, den mehr unlöslichen Anteil in Alkohol bildend und durch längere Ausziehung der ursprünglich gelben Substanz mit Alkohol zurückbleibend, lieferte nach mehrmahliger Umkrystallisation aus verdünntem Alkohol von obigen abweichende Zahlen. Drei Proben als Resultat von drei gesonderten Reinigungsprocessen wurden analysirt. Sie wurden bei 120—125° getrocknet, wobei sie resp. 9.02%, 10.—% und 9.1% Wasser verloren. Auf Trockensubstanz berechnet und nach Abzug von sehr geringen Spuren Asche gaben

I	0.4114 gr.	0.1260 gr.	H_2O	und 0.8989 gr.	CO_2
II	0.4001 „	0.1229 „	„	und ——— „	„ (*)
III	0.3754 „	0.1140 „	„	und 0.8176 „	„

oder in Procenten:

	I	II	III	Mittel	$C_{21}H_{16}O_{11}$(†)
C = 12	59.6	——	59.4	59.5	60.—
H = 1	3.4	3.41	3.37	3.39	3.33
O = 16	37.2	——	37.23	37.11	36.67

Sowohl durch die procentische Zusammensetzung als durch ihre Eigenschaften stimmt diese Substanz sehr nahe mit dem Quercetin überein. Sie bildet gelbe, kleine Krystallnadeln, welche in kaltem Wasser fast unlöslich, schwer löslich in Aether und leicht löslich in heissem, verdünntem Alkohol sind. In Alkalien löst sich das *Asebo-quercetin* mit intensiv gelber Farbe auf, und diese Lösung wird von verdünnter Schwefelsäure stark gelatinös gefällt. Die mit Wasser verdünnte weingeistige Lösung gab mit Eisenchlorid Grünblaufärbung, mit Bleiacetat orangerothen Niederschlag. Letzteres Reagens schlägt es vollkommen aus seinen Lösungen nieder. Conc. H_2SO_4 und HCl färben es hochorangegelb. Mit ammoniakaler Silberlösung, wie auch beim Erwärmen mit alkalischer Kupferlösung tritt starke Reduction ein.

Wird die mit verdünnter Schwefelsäure angesäuerte Lösung in Alkali mit Natriumamalgam versetzt, so tritt beim schwachen Erwärmen die *Stein*sche Paracarthaminreaction ein. Die entstandene rothe Farbe ging durch Alkalien in grün über, und auch die alkalische Lösung des Asebo-quercetins gab sofort mit Natriumalgam Grünfärbung.

Die andere Portion gelben Pulvers, für welche als mittlere Zusammensetzung aus drei gut übereinstimmenden Analysen gefunden war:

54.7 % C
4.34 % H und
40.96 % O,

enthielt, mit den Zahlen für Asebo-Quercetin verglichen, weniger Kohlenstoff (c^a 5%) und mehr Wasserstoff (c^a 1%) als letzteres und war auch in ihren Eigenschaften etwas verschieden. Die Lösung in Alkali wurde nämlich von

(*) Das CO_2 konnte in Folge eines Versehens bei der Wägung nicht bestimmt werden.
(†) Die *Liebermann*'sche Formel für Quercetin

verdünnter Schwefelsäure nicht gefällt, die Paracarthaminreaction trat schon ohne Erwärmung intensiv ein, alkalische Kupferlösung wurde beim Kochen weniger schnell reducirt, und auch die Löslichkeit in Wasser war grösser.

Die erhaltenen Zahlen stimmen aber ziemlich gut mit den für Quercitrin angegebenen Formeln.

	%C	%H	%O
(1) $C_{15}H_{14}O_8$	55.9	4.35	39.75
(2) $C_{33}H_{30}O_{17}$	56.7	4.3	39.0
(3) $C_{36}H_{38}O_{20}$	53.4	4.8	41.8
Asebo-Quercitrin	54.7	4.34	40.96

Nur von der Liebermann'schen Formel.(3) weichen sie etwas erheblich ab. nl. um 1.3% C und etwa 0.5% H. Dies liess sich aber erklären durch einen Gehalt an Quercetin, weil die vollkommene Trennung von Quercetin und Quercitrin nicht leicht gelingt. Durch weitere Umkrystallisation konnte ich auch noch eine kleine Quantität mit den für Quercetin beschriebenen Eigenschaften absondern. Leider ging mir aber eine grosse Quantität bei der Reinigung durch Zerspringen des Becherglases verloren, so dass ich die gereinigte Substanz nicht in genügender Menge erhielt, um neue Elementaranalysen auszuführen. Dieselbe zeigte folgende Eigenschaften:

Schwach hellgelbe, kleine Nadeln, welche in heissem Wasser ziemlich gut, in Alkalien leicht mit intensivgelber Farbe löslich waren. In heissem, verdünnten Weingeist löste es sich ebenfalls leicht auf. Die wässerige, wie die verdünnt alkoholische Lösung gab mit Bleiacetat starken, orange*gelben* Niederschlag, mit Eisenchlorid Blaugrünfärbung, welche durch Alkalien nicht in violett überging. Ammoniakale Silberlösung wurde stark, alkalische Silberlösung beim Kochen *langsam* reducirt. Die alkalische Lösung gab mit verdünnter Schwefelsäure angesäuert *keinen* Niederschlag, und diese Lösung zeigte *ohne* Erwärmen sehr schön die Paracarthaminreaction.

Auch die rothbraune Masse, welche aus dem weingeistigen Extrakte durch starken Alkohol und Aether gefällt war, habe ich noch etwas näher untersucht. Die Masse löste sich in wenig Wasser zu einem klaren dünnen Sirup auf, gab aber auf Zusatz von viel Wasser einen starken hellröthlichbraunen Niederschlag. Dieser wurde abfiltrirt, durch Lösen in wenig Weingeist und Fällung mit Aether oder auch mit Wasser wiederholt gereinigt. Zur Entfernung eines Gehalts an Aschebestandteilen löste ich sie in Weingeist, setzte etwas Salzsäure zu und fällte mit Wasser.

Diese Substanz, welche ich *Asebofuscin* nennen werde, trocknet im

(1) Aus Dragendorff's Quali- und quantitative Analyse von Pflanzen und Pflanzenteilen.
(2) Hlasiwetz und Pfaundler, Kawalier und Rochleder.
(3) Die neueste Formel von Liebermann und Hamburger. Die Spaltung des Glucosides in Quercetin und Isodulcit findet nach folgender Gleichung statt: $C_{36}H_{38}O_{20} + 3H_2O = 2C_6H_{14}O_6 + C_{24}H_{16}O_{11}$.

feuchten Zustande auf dem Wasserbade zu einem dunkelschwarzbraunen Harz zusammen. Bei gewöhnlicher Temperatur getrocknet, bildet es aber ein hellbräunliches Pulver, welches auf dem Wasserbade nicht schmilzt. Es ist in Wasser nicht oder äusserst wenig, in Alkohol leicht mit dunkelbrauner Farbe löslich, nicht löslich dagegen in Aether und Chloroform, wie in kochendem Benzol, ein wenig löslich in kochendem Amylalkohol. In Alkalien löst es sich mit brauner Farbe. Beim Erwärmen mit alkalischer Kupferlösung, sowie mit ammoniakaler Silberlösung ist keine deutlich sichtbare Reduction neben der dunklen Färbung der Flüssigkeit zu beobachten. Die stark mit Wasser verdünnte weingeistige Lösung wird von Eisenchlorid dunkler und grünlich braun gefärbt und gefällt. Bleiacetat bildet in dieser verdünnt-alkoholischen Lösung, ebenso wie ammoniakale Chlorcalciumlösung, hellbraungelben Niederschlag. Goldchlorid giebt dunkelpurpurne Fällung. Mit Natriumamalgam entsteht ebensowenig in saurer Roth-, als in alkalischer Lösung Grünfärbung. Wurde in die alkoholische Lösung unter Erhitzung Salzsäuregas geleitet, so färbte sie sich schön intensiv rothbraun. Wasser fällte daraus einen violetten Niederschlag; dieser wurde nochmals in Weingeist gelöst und mit Wasser ausgefällt. Ihre Lösung in Alkohol ist schön dunkelweinroth. Diese Substanz, welcher der Name *Asebopurpurin* beigelegt sei, löst sich beim Uebergiessen mit Kalilauge darin mit prachtvoll grüner Farbe auf, welche nach einiger Zeit in braun übergeht. Die stark mit Wasser verdünnte weingeistige Lösung gab mit Bleiacetat grünlichen Niederschlag und färbte sich mit Fe_2Cl_6 schmutzigbraun. Getrocknet bildet es ein dunkelviolettliches Pulver.

Sowohl von dem *Asebofuscin* als dem *Asebopurpurin* wurden noch Elementaranalysen gemacht.

Asebofuscin

I 0.3956 gr. der bis 120° getrockneten Substanz lieferten 0.1756 gr. H_2O und 0.8625 gr. CO_2

II 0.4085 gr. der bis 120° getrockneten Substanz lieferten 0.1831 gr. H_2O und 0.8978 gr. CO_2

oder in Procenten:

	I	II	Mittel
C = 12	59.5	59.9	59.7
H = 1	4.93	4.95	4.94
O = 16	35.57	35.15	35.36

Asebopurpurin

I 0.3862 gr. der bis 145° getrockneten Substanz gaben 0.1615 gr. H_2O und 0.9082 gr. CO_2

II 0.3303 gr. der bis 160° getrockneten Substanz gaben 0.1436 gr. H_2O und 0.7696 gr. CO_2

oder in Procenten:

	I	II	Mittel
C = 12	64.1	63.8	63.95
H = 1	4.64	4.83	4.73
O = 16	31.26	31.37	31.32

Weiter habe ich die Untersuchung der Andromeda Japonica Thunb. nicht fortgesetzt; doch dürften die erhaltenen Resultate schon einen vorläufigen Einblick in die Art ihrer Bestandteile geben. Auch habe ich es unterlassen müssen, zu verfolgen, in welcher Form der Stickstoff in dieser Pflanze vorkommt. Eigentümlich ist es, dass das Asebo-purpurin in feuchtem Zustande eine Farbe besitzt, welche auch bei der Einwirkung von Natrium-amalgam auf Asebo-quercetin und- quercitrin auftritt, und dass in allen diesen Fällen diese Farbe durch Alkali in grün übergeht. Das Asebo-fuscin zeigt diese Farbereactionen nicht. Weil auch das Asebotoxin beim Kochen mit verdünnten Säuren dieselbe rothe Farbe erzeugt, welche bei der Einwirkung von Natriumamalgam auf Quercetin in sauren Flüssigkeiten auftritt, (ohne dass diese Farbe nach dem Alkalischmachen in grün überging) scheint mir dieses auf einen einfachen genetischen Zusammenhang der verschiedenen Asebo-bestandteile hinzuweisen.

II. SCOPOLIA JAPONICA MAX.

Diese (wegen ihrer capsula bilocularis operculo circumscissa) den Hyoscyameen angehörende Solanee ist schon häufig Gegenstand von Untersuchungen gewesen, weil sie in ihrer Wirkung der Atropa Belladonna ganz ähnlich zu sein scheint. Ihre Wurzel wird auch gewöhnlich mit dem Namen "Japanische Belladonna" bezeichnet und scheint unter diesem Namen auch schon im europäischen Handel angetroffen zu sein. In Japan werden die daraus dargestellten Galenica, besonders das Extrakt, an der Stelle der Belladonnapräparate therapeutisch verwerthet.

Nach Dr. Martin enthält sie Solanin, nach Dr. Langgaard(*) verdankt sie aber ihre Wirkung zwei Alkaloiden, welche er folgendermassen erhielt. Das erstere wurde aus dem alkoholischen und mit Bleiacetat behandelten Auszuge dargestellt und durch Ausschüttelung mit Chloroform der schwefelsäurehaltigen wässerigen Lösung entzogen: dieses hinterliess beim Verdampfen einen teilweise in zarten Nadeln krystallisirten Rückstand, welcher mit einer gelben schmierigen Materie verunreinigt war. Mit Wasser ausgekocht wurde die Flüssigkeit nach dem Erkalten filtrirt und das Filtrat vorsichtig auf dem Wasserbade bei niedriger Temperatur eingeengt und mit Ammoniak versetzt. Von dem dabei entstandenen weissen Niederschlage wurde abfiltrirt, der Niederschlag auf dem Filter mit wenig Wasser ausgewaschen und in Alkohol aufgenommen, welcher nach seiner Verdunstung farblose Krystalle zurückliess. Es wurde mit dem Namen *Rotoïn* belegt, nach dem japanischen Namen der Pflanze „Roto". Es zeigte das Verhalten eines Alkaloides, wurde aber nur in geringer Menge erhalten, weshalb eine genauere Prüfung nicht vorgenommen wurde. Einige Tropfen der wässerigen Lösung des schwefelsauren Salzes, in das Auge eines Kaninchens gebracht, riefen Pupilleerweiterung hervor. Das zweite Alkaloid, *Scopolein* genannt, wurde in grösserer Menge in der Wurzel aufgefunden und durch weitere Ausschüttelung mittelst Chloroform der alkalisch gemachten Flüssigkeit entzogen. Es bildete eine gelbliche, harzige Masse, die sich in vollkommen trocknem Zustande zu einem gelblich grauen Pulver zerreiben liess und grosse Neigung zusammenzukleben zeigte. Weder das Alkaloid noch seine Salze konnten aber krystallisirt erhalten werden. Auf den tierischen Organismus zeigte es dem Atropin ähnliche Wirkung. Auch in einer Notiz von Holmes (Pharm. Journ. and trans. Apr. 1880) über die botanische Herkunft eines Specimens der Wurzel von Scopolia Japonica findet sich, dass Prof. Flückiger der Ansicht sei, dass darin Atropin vorzukommen scheint.

In der japanischen und chinesischen Literatur findet sich in Kurzem Folgendes: Die Pflanze wächst überall auf Bergen und in Thälern und erreicht eine Höhe von über 1 Fuss. Die Blüthen sind violett oder gelb. Die perennirende,

(*) Mittheilungen der Deutschen Gesellschaft für Natur- und Völkerkunde Ost- Asiens. Yokohama Dec. 1878.

im Frühjahr neue Sprossen treibende, bitter und scharf schmeckende Wurzel, wie auch die Samen sind allgemein als giftig erwähnt und werden bei den folgenden Krankheiten empfohlen:

chronische Katarrhe der Luftwege,
Dysenterie und wässeriger Stuhlgang,
Caries der Zähne, Schlundanschwellung,
Verhärtung der Brustwarzen, schlecht eiternde Furunkel, Prolapsus ani,
Syphilis, Hundsbiss, Krätze, Wechselfieber, Verletzungen mit spitzen Gegenständen u. s. w.(*)

Die meist üblichen Namen sind: Roto 莨菪 und Hashiridokoro ハシリドコロ. Andere Namen, dem Honzokomoku keimo entnommen, sind:

Onishirigusa ヲニシリグサ
Oomirugusa ヲホミルグサ
Yamasa ヤマサ
Nanazugikuya ナヽツ
Koka 虎茄
Sogowo 草牛黄
Gatoshi 牙疼子

Soweit mir bekannt, sind keine weiteren Mitteilungen über die Bestandteile dieser Pflanze gemacht worden. Die obigen, einander widersprechenden und immerhin noch sehr dürftigen Angaben liessen es, mit Rücksicht auf die hiesige therapeutische Verwerthung wünschenswert erscheinen, eine nähere Untersuchung vorzunehmen.

Etwa 10 K° Pulver der frischen, im August von Herrn Tamba (in Nagano-ken) eingesammelten Wurzel der wildwachsenden Pflanze stand uns dazu zur Verfügung. Der grössere Teil(†) wurde mit c^a. 85 procentigem Weingeist einige Male perkolirt und von dem Perkolate der Weingeist bis auf einen Rückstand von etwa 4 Liter abdestillirt. Es schied sich dabei ein fettes Oel ab, die Flüssigkeit reagirte sauer, war hellbräunlich gefärbt und zeigte starke Alkaloidreactionen, wie auch stark reducirende Eigenschaften gegenüber ammoniakaler Silber- und alkalischer Kupferlösung.

Weil das abgeschiedene Oel nicht unbedeutende Mengen fettsaures Alkaloid enthalten konnte, behandelte ich zu deren Zersetzung die Flüssigkeit mit

(*) Im Sanscizuye 三才圖會 findet sich, dass die Samen beim Menschen ein Gefühl verursachen, als ob man den Teufel vor Augen sehe, und dass sie bei Wahnsinn angewendet werden.

(†) Die frische Wurzel eines cultivirten Exemplars enthielt 62.6% Wasser und 1.4% Asche, die Blätter 84.1% Wasser und 2.15% Asche; während letztere nur Spuren Alkaloid enthielten, wurde in 10 Gr. der Wurzel soviel Alkaloid gefunden als mit 8.6 CM^3 $^1/_{20}$ N. Mayers Lösung übereinstimmt. In dem analysirten Pulver der wildwachsenden Wurzel wurde gefunden: 0.61% in Petroleumäther (Spt. 48°), 2.2% in absolutem Aether und 0.59% in absolutem Alkohol lösliche Substanz und 7.18% Asche. In dieser, viel Carbonat enthaltenden Asche wurde von einigen pharmaceutischen Schülern als Mittel aus zwei Bestimmungen, gefunden:

13.8% CO_2, 3.9% SiO_2, 3.4% Cl, 5.1% SO_3, 29.4% K_2O, 5.2% Na_2O und viel P_2O_5, CaO und MgO.

Bleioxyd(*) und liess damit mehrere Tage unter häufigem Umschütteln stehen. Die Flüssigkeit wurde dann zur weiteren Verjagung des Weingeistes noch etwas eingeengt und sodann mit Chloroform wiederholt ausgeschüttelt, bis nichts Bedeutendes mehr aufgenommen wurde. Die Chloroformlösungen wurden dann nach dem Concentriren zwei Male mit schwefelsäurehaltigem Wasser ausgeschüttelt, worin das Alkaloid fast völlig überging. Die Chloroformlösung lieferte aber nach dem Abdestilliren eine ziemliche Menge Krystalle, welchen eine braune Materie beigemischt war. Sie wurden durch Abwaschung mit wenig Chloroform und weiter durch Umkrystallisation aus kochendem Wasser und verdünntem Alkohol gereinigt (Scopoletin).

Die schwefelsäurehaltige Lösung des Alkaloides, welche aus saurer Lösung beim Schütteln mit Chloroform nur Spuren Alkaloid daran abgab, wurde mit Kalicarbonat alkalisch gemacht und dann mit Chloroform ausgeschüttelt. Nach dem Abdestilliren des Chloroforms wurde das rückständige Alkaloid in verdünnter Schwefelsäure gelöst, die Lösung mit Tierkohle behandelt und sodann nach dem Alkalischmachen mit Kalicarbonat wieder ausgeschüttelt.

Im Einklang mit den von Dr. Langgaard gemachten Erfahrungen wurde also 1° eine krystallinische Substanz, aus saurer Lösung, und 2° ein Alkaloid, aus alkalischer Lösung in Chloroform übergehend, gefunden. Weil ich aber mit grösseren Quantitäten arbeitete, konnte ich das letztere Alkaloid fast völlig farblos und grossenteils krystallisirt erhalten. Die aus saurer Lösung übergehende Substanz erwies sich aber als stickstofffrei und scheint mir deshalb das von Dr. Langgaard erhaltene Alkaloid aus saurer Lösung ein Gemisch gewesen zu sein. Die obenerwähnte stickstofflose Substanz besitzt folgende Eigenschaften.

Scopoletin. Farblose, feine Nadeln oder grössere prismatische Krystalle, welche meistens etwas grau- oder gelblich erhalten werden. Sie sind sehr schwer in kaltem, etwas besser in kochendem Wasser, schwer auch in Aether, besser in Chloroform und reichlich in warmem Weingeist und in Essigsäure löslich, unlöslich oder fast unlöslich dagegen in kochendem Schwefelkohlenstoff oder Benzol. Von diesen Lösungen fluoresciren die wässerige, stärker noch die alkoholische schön blau. Die wasserige, mit Säuren versetzte Lösung zeigt violetten Stich, die alkalische Lösung dagegen besitzt gelbe Farbe mit starker blauer Fluorescenz. Das Scopoletin löst sich leicht in Alkalien auf; die wasserige Lösung reagirt schwach sauer auf Lakmus. Die gelbe Lösung in Aetzalkali wird mit Natriumamalgam rothlich braun, welche Farbe beim schutteln mit Luft weinroth wird.

Durch Tierkohle wird es, sogar aus weingeistiger Lösung, fast vollständig fixirt, und es lässt sich dann durch kochenden Alkohol derselben sehr schwierig wieder entziehen. Die Lösung in Ammoniak gab mit absolutem Alkohol krystallinischen Niederschlag, welcher leicht in Wasser mit gelber Farbe und

(*) Hierzu wurde gebraucht das Präcipitat, entstanden durch Versetzen einer warmen Bleiacetatlösung mit frischer verdünnter Kalkmilch. Nach mehrmaliger Auswaschung durch Decanthation wurde der kalkhaltige Niederschlag verwendet.

blauer Fluorescenz löslich war; in dieser Lösung gab $AuCl_3$ kobaltblauen, $AgNO_3$ bläulichen Niederschlag, Fe_2Cl_6 Grünfärbung und grünlich gelben Niederschlag. Auf dem Wasserbade verdampft hinterliess diese Lösung anscheinend unverändertes Scopoletin.

Die ammoniakale Lösung giebt mit Silbernitrat erwärmt langsame, auf Zusatz von etwas Kalilauge starke Silberausscheidung. Es reducirt ebenfalls alkalische Kupferlösung beim Erwärmen. Die wässerige mit verdünnter Schwefelsäure angesäuerte Lösung entfärbt $KMnO_4$ leicht unter CO_2 Entwickelung.

In Eisessig gelöst entfärbt es Brom und giebt damit ein in Nadeln krystallisirendes Substitut, welches in Wasser, Chloroform und Aether schwer, in Alkohol leicht löslich ist.

Für den Schmelzpunkt fand ich 198° (uncorr.) Bei höherer Temperatur verflüchtigt es sich und giebt ein krystallinisches Sublimat, das mit Ammoniak wieder stark blau fluorescirt; es verbrennt zuletzt, ohne Asche zu hinterlassen. Bei 100°-110° getrocknet verlor es kein Krystallwasser. Stickstoff konnte qualitativ nicht nachgewiesen werden.

Elementaranalysen

I 0.2356 gr. der bei 100°-110° getrockneten Substanz lieferten 0.5290 gr. CO_2 und 0.0881 gr. H_2O

II 0.4334 gr. der bei 100°-110° getrockneten, nur aus Wasser umkrystallisirten gelblichen Substanz lieferten 0.9683 gr. CO_2 und 0.1624 gr. H_2O

oder in Procenten:

				Berechnet auf:			
	I	II	Mittel	$C_{12}H_{10}O_5$	$C_{10}H_8O_4$	$C_9H_8O_4$	$C_{18}H_{14}O_8$
C = 12	61.2	60.98	61.1	61.5	62.5	60.—	60.67
H = 1	4.2	4.16	4.18	4.27	4.16	4.44	3.93
O = 16	34.6	34.86	34.72	34.23	33.34	35.56	35.4.

Das Alkaloid, welches durch Tierkohle und durch Ausschüttelung seiner mittelst K_2CO_3 alkalisch gemachten Lösung mit Chloroform etwas gereinigt war, schied sich bei freiwilliger Verdunstung der sehr concentrirten chloroformösen Lösung an den Rändern völlig weiss und in feinen Nadeln krystallisirt und übrigens als eine halb krystallisirte, schwach gelbliche Masse ab, welche aber allmählich mehr und mehr krystallisirte. Die Krystalle waren jedoch wegen ihrer Feinheit nicht mechanisch von der beigemischten amorphen Substanz zu trennen.

Das Alkaloid war in verdünnten Säuren leicht und völlig löslich; diese Lösungen gaben mit allgemeinen Alkaloidreagentien Fällungen(*) und wurden durch Alkalien amorph, farblos gefällt.

Das Alkaloid schmolz noch unter 100° zu einer klaren, farblosen oder schwach röthlich gefärbten Flüssigkeit. Mit concentrirter Schwefelsäure erwärmt

(*) Grenze der Fällbarkeit durch Mayer's Lösung C^a 1 : 15000.

gab es auf Zusatz von Kaliumdichromat oder Ammonmolybdänat starke Entwickelung von Spiräa- und Benzaldehydgeruch.

Von diesem noch unreinen Alkaloide wurde eine Kohlenstoff- und Wasserstoffbestimmung gemacht.

0.3580 gr. der während mehrerer Stunden bei 105-110° getrockneten und geschmolzenen Substanz (wonach sie aber immer noch in Gewicht abnahm durch Verflüchtigung kleiner Quantitäten Alkaloides) gaben:

0.8635 gr. CO_2 und 0.2342 gr. H_2O oder

66.—% C und 7. 3% H.

Eine andere Portion wurde nochmals durch Lösen in verdünnter Schwefelsäure, Behandeln mit Tierkohle und Ausschütteln der mit K_2CO_3 alkalisch gemachten Lösung mit Chloroform gereinigt. Die durch Destillation concentrirte Chloroformlösung war auch jetzt völlig farblos, hinterliess jedoch bei weiterer freiwilliger Verdunstung wieder einen nur zum Teil krystallisirten und völlig weissen Rückstand, welcher sich in ein nicht- zusammenklebendes Pulver verwandeln liess.

II 0.3359 gr. des bei 110° getrockneten und geschmolzenen Alkaloides lieferten:

0.8358 gr. CO_2 und 0.2370 gr. H_2O

III 0.2887 gr. des bei 105°—110° getrockneten Alkaloides ergaben 13.7 Cm^3 feuchten Stickstoff bei 18° und 758^{mm}

also in Procenten:

		Tropeïn der Tropasäure $C_{17}H_{23}NO_3$
C = 12	67.9	70.58
H = 1	7.84	7.95
N = 14	5.4	4.84
O = 16	18.86	16.61

Wenn auch diese Zahlen noch nicht sehr genau mit den für $C_{17}H_{23}NO_3$ berechneten übereinstimmen, was wohl wegen der Unreinheit zu erwarten war, scheinen sie mir nicht in Widerspruch mit der Vermutung, dass in der Scopolia ein krystallisirtes Tropein vorhanden ist.

In kleineren Quantitäten erhielt ich es in völlig weissen Warzen von kleinen Krystallnadeln ohne sichtbare Beimischung einer gelben amorphen Substanz. Ihre wässerige Lösung gab mit Goldchlorid eine gelbe ölige Fällung, welche in der Wärme sich ganz oder zum Teil löst und beim Abkühlen sich wieder goldglänzend krystallinisch ausscheidet; unter dem Mikroskope zeigte es Blättchen, welche nicht sehr regelmässig begrenzt waren. $PtCl_4$ giebt einen zusammenklebenden Niederschlag; in stark verdünnten Lösungen tritt aber keine Fällung ein. Weil die Wahrscheinlichkeit vorliegt, dass das erhaltene Alkaloid, wofür der Name Scopolein beibehalten sei, welchen Dr. Langgaard

für das von ihm erhaltene, amorphe, graue Pulver wählte, aus mehreren Tropeinen (vielleicht Hyoscyamin und Hyoscin) besteht, habe ich keine weiteren Versuche vorgenommen zur Trennung; die erhaltene Quantität reichte dazu nicht aus. Dass aber ein den natürlichen Alkeïnen der Solaneen nahe verwandtes Alkaloid in der Scopolia vorhanden ist, konnte ich noch durch einen Spaltungsversuch mittelst Barytwasser weiter darthun. Es wurde dabei nämlich eine Säure erhalten, welche in ihren Eigenschaften, soweit sie untersucht wurde, völlig mit den der Atropasäure übereinstimmten. Etwa ein halbes Gramm des *Scopoleïns* wurde mit der doppelten Menge Barythydrat und der dreissigfachen Menge Wasser in einer zugeschmolzenen Röhre während einiger Tage im Wasserbade erhitzt. Beim Oeffnen der Röhre gab sich ein Spiräa- Geruch zu erkennen; der Inhalt wurde filtrirt, wobei eine sehr kleine Menge eines harzigen Körpers zurückblieb. Beim Ansäuern des Filtrates mit Salzsäure trat der obenerwähnte Geruch stärker auf und schieden sich nach kurzer Zeit Krystalle aus, welche durch einmalige Umkrystallisation aus heissem Wasser völlig farblos und von vorzüglicher Reinheit erhalten wurden. Sie besassen folgende Eigenschaften:

Platte, glänzende, farblose Nadeln, welche in kaltem Wasser schwer, in heissem leicht, reichlich in Alkohol, Essigsäure, Aether, Chloroform und Schwefelkohlenstoff, ziemlich in warmem Benzol löslich sind. Auch sind sie leicht in Alkalien löslich. Die wässerige Lösung reagirt sauer, verbreitet beim Erwärmen den Geruch der Atropasäure (nach Spiräa & Benzoesäure) und giebt mit essigsaurem Blei weissen Niederschlag. Mit ammoniakaler Silberlösung erwärmt findet keine, auf Zusatz von etwas Kalilauge aber starke Reduction statt. Auch alkalische $AuCl_3$ Lösung wird beim Erwärmen reducirt. Für den Schmelzpunkt fand ich 104° C (uncorr.) und 105.°3 (corrig). Weiter erhitzt entsteht ein krystallisirendes Sublimat und bleibt zuletzt keine Spur Asche zurück. Diese Eigenschaften stimmen mit denen der Atropasäure (Schmpt. 106°) überein.

In concentrirter Schwefelsäure löste es sich farblos, und diese Lösung nahm auf Zusatz von etwas Salpetersäure intensiv wein-bis braunrothe Färbung an.(*)

Das Filtrat der durch Salzsäure gefällten Atropasäure lieferte nach dem Alkalischmachen mit Ammoniak, Ausschütteln mit Aether und freiwilliger Verdunstung der ätherischen Lösung einen amorphen bräunlich gefärbten Rückstand, der einen etwas anilinähnlichen Geruch besass und im Exsiccator geringe Krystallisation zeigte. Seine Lösung in verdünnter Salzsäure gab mit $PtCl_4$, $AuCl_3$ und Mayer's Lösung Trübungen. Die Quantität dieses wahrscheinlich unreinen Tropins war zur weiteren Untersuchung nicht ausreichend.

(*) Bald nachher hatte ich Gelegenheit diese Reaction mit aus Europa bezogener Atropasäure anzustellen. Sie verhielt sich völlig der aus Scopoleïn erhaltenen Säure gleich. Eine Probe Tropasäure zeigte sich in dieser Beziehung von der Atropasäure verschieden, indem sie sich in conc. Schwefelsäure schwach röthlich, fast farblos löste, welche Lösung aber auf Zusatz von Salpetersäure vollkommen farblos blieb.

Die ursprüngliche mit Bleioxyd behandelte und mit Chloroform ausgeschüttelte Flüssigkeit gab nach dem längeren Stehen einen fast weissen krystallisirten Absatz in ziemlich grosser Menge. Dieser wurde gesondert, wonach die Flüssigkeit beim weiteren Eindampfen noch eine neue Quantität lieferte. Sie wurde mit kaltem Wasser ausgewaschen und durch Umkrystallisation aus verdünntem Alkohol oder Wasser gereinigt.

Diese Substanz, *Scopolin*, welche sich als das Glucosid des schon beschriebenen Scopoletins herausstellte, besitzt folgende Eigenschaften.

Scopolin. Weisse, nadelförmige Krystalle, welche ziemlich in kaltem, leicht in warmen Wasser wie in Weingeist löslich sind. Sie sind unlöslich in Aether und Chloroform. Die wässerige Lösung reägirt neutral und reducirt auch beim Kochen alkalische Kupferlösung nicht. Nach dem Kochen mit verdünnten Mineralsäuren dagegen findet starke Reduction statt. Mit ammoniakaler Silberlösung färbt sich die Flüssigkeit beim Kochen gelb und giebt allmählich Silberausscheidung, welche auf Zusatz von Kali sogleich stark eintritt. In concentrirter Salpetersäure löst es sich mit gelber Farbe. Die gelbe Lösung in conc. Schwefelsäure fluorescirt blau. Schmelzpunkt 218° (uncorr.).

I 0.4385 gr., lufttrocken, lieferten nach dem Trocknen bei 105° 0,4100 gr. und beim Verbrennen 0.7608 gr. CO_2 und 0.1990 gr. H_2O

II 0.3393 gr. bei 120° getrocknet gaben 0.3174 gr. Trockensubstanz und 0.5878 gr. CO_2 und 0.1530 gr. H_2O

oder in Procenten, auf getrocknete Substanz berechnet:

	I	II	Mittel	Berechnet auf. $C_{24}H_{30}O_{15}$
C = 12	50.6	50.5	50.55	51.6
H = 1	5.4	5.36	5.38	5.37
O = 16	44.–	44.14	44.07	44.03

Bei der ersten Analyse wurde 6,5%, bei der zweiten 6.9% H_2O, auf Trockensubstanz berechnet, gefunden. Die Formel $C_{24}H_{30}O_{15}$. 2 H_2O verlangt 6.45%. Stickstoff konnte weder qualitativ noch quantitativ nachgewiesen werden.

0.3388 gr. der bei 105° getrokneten Substanz lieferten nach der Methode Dumas analysirt nur eine geringe Menge Gas, welche ich nicht weiter genau bestimmte, weil sie höchstens 0.2% betrug, also innerhalb der Fehlergrenzen der Analyse liegt.

0.8068 gr. des lufttrocknen Scopolins lieferten nach dem längeren Kochen mit verdünnter Schwefelsäure und Filtration der völlig erkalteten Flüssigkeit und Auswaschen mit Wasser 0.3033 gr. = 37.6% eines in Nadeln krystallisirenden Zersetzungsproduktes.

Das Filtrat wurde mit Baryumcarbonat behandelt und nach der Neutralisation filtrirt. Das Filtrat, zum Trocknen verdampft, lieferte einen weisslichen syruposen Rückstand. Weil er eine Barytverbindung enthielt, warscheinlich des gelöst gebliebenen Zersetzungsproduktes, habe ich auf die quantitative Bestimmung verzichtet; doch konnte ich durch wiederholte Ausziehung mit starkem

Alkohol 0.2561 gr. einer barytfreien, klaren und schwach gelblich gefärbten amorphen Substanz erhalten, welche das Reductionsvermögen der Glucose zeigte. Die 0,2561 gr. (bei 110° getrocknet), wurden in 50 Cm^3 Wasser gelöst und mit *Fehling*' scher Kupferlösung titrirt. Für 10 Cm^3 derselben wurden im Mittel 9.8 Cm^3 verbraucht, während für reine Glucose 9.76 Cm^3 verlangt werden.

Ein andermal wurden aus 1.2 gr. des lufttrocknen Scopolins durch Kochen mit verdünnter Salzsäure 0.4571 gr. = 38.1% des unlöslichen Zersetzungsproduktes erhalten.

Von einer gesondert gereinigten Quantität Scopolin, welche mehrere Tage unter dem Exsiccator gestanden hatte, wurden 0.4135 gr. nochmals zur H_2O Bestimmung gebraucht. Durch Trocknen bis 155° verlor es 0.0275 gr. = 6.65% H_2O.

1.3035 gr. dieses unter dem Exsiccator getrockneten Scopolins gaben mit 20 Cm^3 (1 : 10) verdünnter Schwefelsäure gekocht 0.4894 gr. des krystallinischen Zersetzungsproduktes. Zur Entfernung des noch gelösten Anteils wurde das Filtrat dann wiederholt mit Chloroform ausgeschüttelt, welches nach dem Abdestilliren noch 0.0154 Gr. krystallisirten Rückstand liess. Es waren daher im Ganzen 0.5048 gr. = 38.73% des krystallisirten Zersetzungsproduktes erhalten. Das von dem Chloroform getrennte Filtrat wurde fast völlig neutralisirt, erwärmt und nach Abkühlung bis 100 Cm^3 verdünnt. Von dieser Flüssigkeit wurden im Mittel 6.62 Cm^3 für 10 Cm^3 Fehling's Lösung verbraucht, woraus sich eine Quantität von 0.772 gr. = 59.2% Glucose berechnen lässt. Ein andermal erhielt ich aus 0.6498 gr. unter dem Exsiccator getrockneten *Scopolins* durch Kochen mit (1 : 10) verdünnter Schwefelsäure 35.3% des krystallisirten Zersetzungsproduktes (Schmpt. 197.°5). Das Filtrat mit Ba CO_3 behandelt gab, bei 110° getrocknet, 0.419 gr. = 64.5% Rückstand, wovon 0.071 gr. beim Behandeln mit Aether-Alkohol in Lösung gingen und der Rest in 50 Cm^3 Wasser gelöst einen Reductionswerth von 0.313 gr. Glucose zeigte.

Das krystallinische Zersetzungsprodukt, welches beim Kochen des Scopolins mit verdünnten Mineralsäuren als völlig farblose Nadeln sich ausscheidet, besitzt nach dem Trocknen gewöhnlich eine grauliche Farbe und konnte als identisch mit dem schon beschriebenen Scopoletin erkannt werden. Es zeigte den Schmelzpunkt 197°—198° (uncorr.) und weiter dieselben Reactionen wie oben beschrieben. Auch gab eine Elementaranalyse Zahlen, die gleichfalls völlig mit den für Scopoletin gefundenen übereinstimmten.

0.3213 gr. bei 100°—105° getrocknet, lieferten

0.7233 gr. CO_2 und 0.1170 gr. H_2O oder 61.41% C und 4.05% H.,

indem für das *Scopoletin* früher gefunden war im Mittel 61.1% C und 4.18 H (Seite 19).

Die Spaltung des *Scopolins* durch Säuren liess sich vorläufig am besten durch die Gleichung

$$C_{24}\,H_{30}\,O_{15}.\,2\,H_2O = 2\,C_6\,H_{12}\,O_6 + C_{12}\,H_{10}\,O_5$$

ausdrücken. Dieselbe verlangt 39.4% Scopoletin und 60.6% Glucose. Das *Scopolin*

hat keine dilatirende Wirkung auf die Pupille, das *Scopolein* dagegen wirkt stark mydriatisch. 0.100 gr. Scopolin, einem Hunde subcutan eingespritzt, verursachten mehreren Stunden Schlafsucht, ohne den Tod herbeizuführen, während ein Tropfen einer Lösung des Scopoleins (1 : 5000) beim Kaninchen, stärker beim Menschen Dilatation der Pupille zeigte.

Die sirupöse Flüssigkeit, welche von dem auskrystallisirten *Scopolin* abfiltrirt war, wurde mit K_2CO_3-Lösung alkalisch gemacht und wieder mit Chloroform ausgeschüttelt. Das Chloroform hinterliess beim Abdestilliren nur eine unbedeutende Quantität Alkaloid, in Form eines braun gefärbten amorphen Rückstandes. Die ausgeschüttelte Flüssigkeit lieferte nach dem Ansäuern, Eindampfen und langem Stehen noch eine ziemliche Menge des Scopolins. Die davon getrennte sirupöse braune Masse, welche anscheinend sehr grosse Mengen Glucose enthielt und noch starke Alkaloidreactionen zeigte, habe ich ebensowenig, wie den braunen, wahrscheinlich tropinhaltigen, alkaloidischen Rückstand, weiter untersucht.

Das Vorkommen eines den Alkeinen der Tropasäure nahestehenden Alkaloides, wie auch eines Glucosids Scopolin mit seinem Zersetzungsprodukte, dem Scopoletin, macht die Scopolia Japonica Thunb. zu einer höchst interessanten Pflanze und hoffe ich mir gelegentlich grössere Quantitäte der beschriebenen Bestandteile verschaffen zu können, um weitere Versuche über ihre Constitution anzustellen. Ob auch in den übrigen therapeutisch verwertheten Solaneen dieses Glucosid vorkommt, dürfte wohl angezweifelt werden auf Grund der Häufigkeit, womit diese Pflanzen Gegenstand von Forschungen waren. Andererseits scheint mir das Vorkommen einer fluorescirenden Substanz in der *Atropa Belladonna* die Möglichkeit des Vorhandenseins eines solchen oder ähnlichen Glucosides nicht unwahrscheinlich zu machen und beabsichtige ich die Radix Belladonnae in dieser Richtung nochmals zu pruefen.

III. MACLEYA CORDATA. R. Br.(*)

Diese als Giftpflanze bekannte Papaveracee(†) (Subtrib. Bocconieae) wächst hier fast überall auf Hügeln und Bergen an uncultivirten Stellen. Sie erreicht eine Höhe von bis c^a 2 M., ihre Blätter sind bis 30 Ctm lang, und beim Verletzen des Stengels, der Wurzel, Blattnerven und Früchte fliesst ein orangegefärbter Milchsaft aus. Blüthezeit Juli. Die meist üblichen Namen sind: Takenigusa タケニグサ, Tsiampangiku チヤムパギク und Tachiobaku タチオバク. Der chinesische Name ist Hakurakukuai 博落廻(‡)

Auszüge der frischen, zerkleinerten Wurzel, Blätter und jungen Früchte (1:10), durch Maceration mit schwefelsäurehaltigem Wasser, und Mischen mit dem dreifachem Volum Weingeist angefertigt, wurden nach Filtration und Verdampfen des Filtrates, zuletzt unter Zusatz von etwas Wasser, mit $\frac{N}{20}$ Mayer's Lösung titrirt und die entstandenen Niederschläge durch Maceration mit Weingeist in ein lösliches und ein unlösliches (Sanguinarin-) Doppeljodid getrennt. Es zeigte sich dabei, dass der Alkaloidgehalt der Wurzel und Blätter (c^a 0.5-1. proc.) fast gleichgross ist, wie in Chelidonium majus(§). Auf Trockensubstanz berechnet, enthielten die Früchte am meisten, die Wurzel viel weniger und die Blätter am wenigsten Sanguinarin, während der Gehalt an Alkaloid des in Alkohol löslichen Doppeljodids für Wurzel und Blätter fast derselbe, für die Früchte etwas geringer war. Ziemlich grosse Mengen der Wurzel wurden zur Erhaltung der beiden Alkaloide in Arbeit genom-

(*) Diese Untersuchung, welche hier in Auszug aufgenommen sei, weil sie sich der des Chelidoniums anschliesst, wurde schon vor einigen Jahren von mir an dem Tokio Shiyakujio ausgeführt (Beitrag z. Kenntn. der Papaveraceen-Alkaloide. Yokohama 1881). Eine andere Untersuchung, ebendaselbst angefangen, die des Illicium religiosum Sieb., hoffe ich bald wieder aufnehmen zu können und in mehr eingehender Weise fortzusetzen.

(†) Herba sinica, perennis; radice repente, foliis alternis, petiolatis, subrotundis, basi cordatis, obsolete lobatis, grosse et obtuse dentatis, venosis, membranaceis, subtus glauco-albidis; paniculae terminales, elongatae, laxae ramis erectis, paucis, ramulisque unibracteatis. Calyx diphyllus, foliolis coloratis, ovatis caducis. Corolla nulla. Stamina 24-48, hypogyna; filamenta, filiformia, antherae biloculares, elongato-lineares, latere longitudinaliter dehiscentes. Ovarium sessile, ovatum compressum. Ovula juxta placentas intervalvulares oppositas utrinque 2-8, horizontalia, anatropa. Stigma subsessile, bilobum, lobis oblongis. Capsula subcompressa, unilocularis, bivalvis, tetra-hexasperma, valvis, a basi solutis, deciduis, replo annulari seminifero persistente. Semina horizontalia, ovata, testa crustacea, basi superne strophiolata. Embryo in basi albuminis carnosi minimus; cotyledonibus nunc tribus aequalibus, nunc duabus vel quatuor inaequalibus, germinatione petiolatis, ovato-subrotundis. Radicula umbilico proxima, centrifuga.— (Endlicher, *Systema Plantarum*, 4817.)

(‡) Andere Namen sind:

Sosoyaki ソソヤキ, Gurogi ゴウロギ, Kenkuagusa ケンクワグサ, Tsukeishi ツケイシ, Takato タカトウ, Urajiro ウラジロ, Okamedaoshi ヲーカメダヲシ, Kajigusa カジグサ, Sasayakigusa ササヤキグサ.

Die Pflanze wird hier zum Färben von Bambus verwendet; daher der Name Take-ni-gusa (Bambus- koch- Kraut).

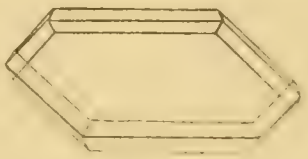
Der Name Kara-Kachiba, von *Franchet und Savatier* (Enumeratio Plantarum) erwähnt, ist irrtümlich der nächsten Seite im *Honzo-zufu* entnommen (Fol. 24 Vol. 21). Derselbe gehört der Ricinus communis an.

(§) Dragendorff, Chem. Werthbestimmung einiger starkwirkenden Drogen p. 100.

men. Auszüge mit verdünnter Schwefelsäure und Weingeist angefertigt, wurden nach dem Abdestilliren des Weingeistes mit Ammoniak übersättigt und der Niederschlag nach dem Trocknen mit Aether ausgezogen bis dieser nicht mehr gelb gefärbt wurde. Salzsäure fällte aus der ätherischen Lösung einen scharlachrothen Niederschlag, welcher das salzsaure Salz eines, nach dem Reinigen chemisch und physiologisch mit Sanguinarin übereinstimmenden, Alkaloides bildete. Der in Aether ungelöst gebliebene Anteil wurde mit Weingeist ausgezogen, der Weingeist abdestillirt, der Rückstand mit Essigsäure behandelt bis zur schwach sauren Reaction und dann mit soviel Wasser versetzt, bis keine Ausscheidung mehr stattfand. Aus dieser Lösung wurde ein Alkaloid erhalten, welches nach völliger Reinigung folgende Eigenschaften zeigte.

Macleyin. In Wasser und Alkalien fast unlöslich; kalter Weingeist löst fast nichts, heisser etwas mehr: diese Lösungen reagiren alkalisch. In Aether sehr wenig löslich, besser in frisch gefälltem Zustande; schüttelt man nämlich mit Ammoniak versetzte Macleyinsalzlösungen mit Aether aus, so geht das Alkaloid leicht darin über, scheidet sich aber nach kurzer Zeit grossenteils wieder aus, in Form von Kugeln oder mehr oder weniger gut ausgebildeten, an den Enden abgestumpften oder abgerundeten Prismen. Benzol löst das Alkaloid in der Kälte sehr wenig, in der Siedehitze besser.

Chloroform löst ziemlich gut, namentlich in der Wärme. Aus der concentrirten Lösung fällt Aether das Macleyin wieder aus, bei langsamer Ausscheidung in Formen wie Figur.



Das Alkaloid hat keinen Geschmack, seine Salze schmecken bitter, nachher scharf und kühlend. Für den Schmelzpunkt fand ich 201° (uncorr.).

Bei 100° verliert es kein Krystallwasser.; die annähernden Löslichkeitsbestimmungen bei gewöhnlicher Temperatur ergaben für

90% Weingeist	1 : 900
officinellen Aether	1 : 1000
Chloroform	1 : 15

Elementaranalysen:

0.31075 gr. lieferten 0.15325 gr. H_2O und 0.7749 gr. CO_2
0.3030 „ „ 0.1488 „ „ „ 0.7515 „ „
0.3107 „ „ 0.1505 „ „ „ 0.7740 „ „
0.4528 „ „ 16.69 Cm^3 feuchten N_2 bei 22° C und 764^{mm} (corr.)
0.4691 „ „ 17.2 „ „ „ „ 23°.5 C und 765 „ (corr.)

oder in Procenten:

	I	II	II	Mittel		Berechnet auf			
C = 12	67.98	67.64	67.94	67.85	C_{20}	67.98	C_{40}	67.80	C_{21} 69.31
H = 1	5.48	5.46	5.38	5.44	H_{19}	5.38	H_{40}	5.65	H_{19} 5.20
N = 14	4.19	4.14	—	4.16	N	3.97	N_2	3.98	N 3.83
O = 16	—	—	—	—	O_5	22.67	O_{10}	22.57	O_5 21.66

0.802 gr. des bei 100° C. getrockneten Platindoppelsalzes lieferten
0.1396 gr. Platin = 17.4% (Pt = 194.5)
Die Formel $(C_{20}\,H_{19}\,NO_5\,.\,HCl)_2\,PtCl_4$ verlangt 17.43% Pt.

Das Macleyin zeigt folgende Reactionen:

Mit *reiner*, frisch destillirter Schwefelsäure färbt sich ein Krystall gelb, alsbald ziehen sich aber Streifen von dem Alkaloide ab, welche die Schwefelsäure *violett* färben, während das Krystall fast schwarz erscheint. Wendet man zu Pulver zerriebenes Alkaloid an, so färbt es sich zwar momentan gelb, die Schwefelsäure wird aber sofort prachtvoll *dunkelviolett;* nach einiger Zeit, schneller bei sanfter Erwärmung, z. B. auf dem Wasserbade, geht die Farbe in *grasgrün* über, schliesslich verändert sie sich in bräunlichgelb und die Flüssigkeit entfärbt sich zuletzt fast völlig. In Berührung mit *HNO_3—Dämpfen* entwickelt sich eine prachtvolle *ultramarinblaue* Farbe. Bewegt man einige Körnchen des Alkaloides durch *HNO_3 haltige Schwefelsäure*, so entsteht eine prachtvoll *blaue* oder bei etwas grösserem HNO_3 Gehalt *dunkelgrüne* Färbung, die bald in braun übergeht.

HNO_3 von 1.2 spec. Gew. löst es ohne Färbung; mit gelber Farbe wird es von HNO_3 von 1.34 spec. Gew gelöst.

Von *eisenoxydhaltiger* H_2SO_4 wird es wie von reiner Schwefelsäure gelöst; nur ist die Nuance mehr blauviolett. Bei Erwärmung verwandelt sich die Farbe ebenfalls in *grün.*

Die Lösung in Schwefelsäure wird auf Zusatz von *Kalidichromat* intensiver *blau* gefärbt.

Molybdänsäurehaltige H_2SO_4 giebt dunkelpurpurne, blaue und grüne Färbung.

Eisenchlorid färbt nicht, auch wird ein Gemisch von $Fe_2\,Cl_6$ und $K_6\,Fe_2\,Cy_{12}$ nicht reducirt. Mit den ungefärbten Säuren liefert das Macleyin farblose Salze, welche sich alle, soweit sie untersucht wurden, in Krystallen darstellen liessen; die in Wasser leicht löslichen scheiden sich beim Verdampfen ihrer Lösungen in der Wärme oft amorph aus, die schwer löslichen werden entweder amorph oder in Form von Kugeln, Warzen, kleinen Prismen oder Nadeln gefällt. Beim Eintrocknen schrumpfen manche, wie dies auch mit dem durch Alkalien gefällten Alkaloid der Fall ist, zu einem bedeutend kleineren Volum zusammen. Die Salze gelatiniren nicht. Ihre Lösungen werden allmählich, schneller beim Erwärmen, gelblich gefärbt und geben mit allgemeinen Alkaloidreagentien, auch mit $HgCl_2$, $K_2\,Cr_2\,O_7$, KJ, CN.SK, Fällungen.

Hydrochlorat. Schiesst aus seiner wässerigen, neutral reagirenden Lösung in 4-6 seitigen Prismen an. Löslichkeit in Wasser etwa 1 : 140.

Hydrojodat. Jodkaliumlösung giebt in Macleyinsalzlösungen einen käsigen, weissen Niederschlag, der nach einiger Zeit zusammenschrumpft. Unter dem Mikroskope zeigt es sich im Form von Kugeln : es löst sich seh rwenig in kaltem besser in heissem Wasser und Alkohol. Aus letzterer Lösung konnte das Salz in kleinen Krystallen erhalten werden.

Sulphat (neutrales). Farblose Nadeln, in Wasser und Alkohol löslich, neutral reagirend. Wird die wässerige Lösung bei 100° verdunstet, so trocknet sie hornartig ein und löst sich dann sehr leicht in Wasser zu einer übersättigten Lösung, welche auf Zusatz von etwas verdünnter Schwefelsäure weisse krystallinische Fällung giebt. Dasselbe wurde mit dem Hydrochlorat beobachtet.

Chromat. Kalidichromat erzeugt in Macleyinlösungen einen orangegelben Niederschlag, welcher in heissem Wasser gut löslich ist und in Prismen erhalten werden kann.

0.1914 gr. dieses bei 100° getrockneten Salzes lieferten 0.031 gr. $Cr_2 O_3$. Die Formel $(C_{20} H_{19} NO_5)^2 H_2 Cr_2 O_7$ verlangt 0.0316. gr.

Das Salz löst sich mit *prachtvoll blauer* Farbe in concentrirter Schwefelsäure auf.

Platindoppelchlorid. Platinchlorid fällt Macleyinlösungen weisslichgelb. Der Niederschlag löst sich beim Kochen ziemlich leicht auf. Beim Austrocknen an der Luft schrumpft das Salz stark zusammen und löst sich dann sehr wenig in Wasser.

0.8313 gr. des lufttrocknen Salzes verloren bei 100° 0.0255 gr. $H_2O = 3.07\%$

0.802 gr. dieses getrockneten Salzes lieferten 0.1396 gr. Platin = 17.4%.

0.2926 gr. des lufttrocknen Salzes verloren bei 110° getrocknet 0.0095 gr. = 3.24%

Die Formel $(C_{20} H_{19} NO_5 . HCl)^2 PtCl_4 + 2 H_2O$ verlangt 17.43% Pt (auf wasserfreies Salz berechnet) und 3.14% H_2O

Quecksilberdoppeljodid. Jodkaliumquecksilberjodid giebt in Macleyinsalzlösungen einen amorphen, käsigen, weissen Niederschlag, welcher beim Kochen zu einer geschmolzenem Schwefel ähnlichen Masse schmilzt und in Weingeist gut löslich ist.

Thiocyanat. Rhodankalium erzeugt in Macleyinsalzlösungen eine weisse Fällung, die beim Erwärmen leicht verschwindet und bei Abkühlung wieder in Blättchen oder sternförmig gruppirten Nadeln ausscheidet.

Acetat. Krystallisirt in bündel- oder sternförmig gruppirten Nadeln und ist in Wasser und Alkohol gut löslich.

Saures Oxalat. Wird Macleyin mit Wasser und überschüssiger Oxalsäure erwarmt, so scheidet nach Abkuhlung das saure Salz in warzenförmig gruppirten feinen Nadeln aus. Es löst sich schwer in kaltem, gut in heissem Wasser.

Saures Tartrat. Sternförmig gruppirte Nadeln, in kaltem Wasser schwer löslich.

Pikrat. Pikrinsaures Kali erzeugt in den Alkaloidsalzlösungen einen gelben Niederschlag. Das Pikrat ist in kochendem Wasser sehr schwer löslich. Mit conc. $H_2 SO_4$ färbt es sich prachtvoll blau.

Benzoat. Lange, weisse, seidenglänzende Nadeln, welche sehr schwer in kaltem, etwas besser in heissem Wasser und gut in warmem Weingeist löslich sind. Es schmilzt bei 166° (uncorr.) zu einer röthlichen Flüssigkeit.

Beim Vergleich des *Macleyins* mit den besser bekannten Papaveraceen-Alkaloiden stimmen seine Eigenschaften mit dem von *Hesse* entdeckten Opiumalkaloide *Protopin* auffallend überein, nl. in der *characteristischen Kugel- und Warzenform der Aetherausscheidungen, der Löslichkeit in verschiedenen Menstrua, der Formel, der Zusammensetzung des Platindoppelsalzes u. s. w.*, Der Schmelzpunkt 201° (uncorr.), 205° (corr.) weicht nur wenig von dem von Hesse(*) für *Protopin* gefundenen 202° ab. Auch mit den Alkaloiden der übrigen Papaveraceen, welche farblose Salze bilden, Chelidonin, Glaucopikrin, Sanguinariaporphyroxin u. s. w. stimmt das Macleyin in der violetten und grünen Farbe, welche sie mit H_2SO_4 erzeugen, überein. Das Chelidonin verhält sich weiter dem Macleyin, und auch Protopin, Kryptopin, Lanthopin in der schwierigen Löslichkeit in Alkohol und Aether, sowie des Hydrochlorats in Wasser, ähnlich, weicht aber wesentlich von diesen Basen durch seinen niedrigeren Schmelzpunkt (130° *Will*) und durch seine Zusammensetzung $C_{19} H_{17} N_3 O_3$ ab. Dieser hohe Stickstoffgehalt des Chelidonins scheint aber zweifelhaft, weil in allen anderen analysirten Papaveraceen-Alkaloiden auf 1 Mol. (1 Aeq) nur ein Stickstoffatom vorkommt, und ich hielt es daher nicht für überflüssig, eine weitere Prüfung vorzunehmen.

(*) Beitr. z. Kenntniss d. Opiumbasen. Arch. d. Pharm. Jahrg. 51 Bd. CC. p. 117., Ann. d. Chem. u. Pharm. VIII Supplementband. 3. Heft (Jan. 1872).

IV. CHELIDONIUM MAJUS.

In dem vorigen Aufsatze über Macleya cordata sprach ich die Vermuthung aus, dass die bis jetzt für das Chelidonin adoptirte Formel C_{19} H_{17} N_3 O_3 mit Hinsicht auf den Stickstoffgehalt nicht richtig sei, mich dabei stützend auf die Analogie mit den übrigen besser untersuchten Papaveraceen- Alkaloiden. Letztere enthalten alle auf ein Aequivalent der Base nur ein Stickstoffatom, während das Chelidonin, welches dem Macleyin, Protopin u. s. w. nahe verwandt scheint, drei Stickstoffatome enthalten soll. *Will* fand nämlich als Resultate von Elementaranalysen(*)

C = 67.4 — 68.1%
H = 5.6%
N = 12.2%

und für den Platingehalt des Platindoppelsalzes 17.4-17.6%. Aus diesen Zahlen berechnete er die Formel C_{21} H_{21} N_3 O_3, wofür später, mehr in Uebereinstimmung mit dem Gesetze der paaren Atomzahlen, andere vorgeschlagen wurden, von welchen die Formel C_{19} H_{17} N_3 O_3 jetzt allgemein in chemische Werke übergegangen ist.

Elementaranalysen, welche sowohl mit hier dagestelltem Chelidonin, wie mit aus Deutschland bezogenem angestellt wurden, bestätigten diese Vermuthung und zeigten, dass auch hier auf ein Aequivalent der Base nur ein Stickstoffatom kommt.

Aus hier gesammelter und grob gepulverter Wurzel des Chelidonium majus(†), wurde von Herrn Tamba das Chelidonin durch Auskochen mit H_2SO_4- haltigem Wasser und Fällung der Auszüge mit Ammoniak dargestellt. Der abgewaschene und getrocknete Niederschlag wurde mit schwefelsäurehaltigem verdünntem Weingeist ausgekocht und das Filtrat nach dem Verdünnen mit Wasser durch Natronlauge gefällt. Der Niederschlag wurde getrocknet, mit Aether zur Entfernung von Sanguinarin ausgewaschen und das ungelöst gebliebene Alkaloid durch Lösen in H_2SO_4 haltigem Weingeist und Freistellung durch Natronlauge gereinigt; durch freiwillige Verdunstung der weingeistigen Lösung wurden zuletzt etwa 2.5— 3 gr. ziemlich grosse und gut gebildete Krystalle erhalten.

In concentrirter Schwefelsäure löste es sich anfangs farblos, bald bildeten sich schwach bräunliche Streifen, welche nachher dunkelviolett wurden; bei

(*) Gmelin Handb. der organ. Chemie. IV. Bd. p. 1684. — C_{20} H_{19} N_3 O_3 (Gerhardt) C_{21} H_{19} N_3 O_3 (Gmelin). C_{19} H_{17} N_3 O_3 Limpricht (Lehrb. 1197).

(†) Chin: Hakutsusai 白屈菜, oder Kusa no Oo = König der Kräuter 草ノ王. Die Blätter sollen nach Yamatohonzo, äusserlich in feingeriebenem Zustande applicirt, bei Syphilis und Geschwulsten wirksam sein. Die Pflanze kommt hier wiewohl überall doch nur sparsam vor und konnte deshalb nur eine kleine Quantität der Wurzel auf Chelidonin verarbeitet werden.—

Anwendung von etwas weniger concentrirter H_2SO_4 schien die Färbung etwas schöner einzutreten. Conc. H_2SO_4 mit einer Spur HNO_3 färbt das Alkaloid grün. In starker HNO_3 löst es sich mit gelber Farbe.

Als Schmelzpunkt fand ich 135°-136° C (uncorr.). Bei Temperaturen nahe am Schmelzpunkt gelegen färbte das Chelidonin sich röthlich braun, beim stärkeren Erhitzen purpurroth unter Bildung eines krystallinischen Sublimats und Entwickelung von Dämpfen, welche Methylamin- und Benzœsäuregeruch verbreiteten.

Bei 100° während mehrerer Stunden getrocknet, verlor es nur Spuren Wasser. Nach *Will* verliert das mit einer Molekel Wasser krystallisirte Chelidonin schon bei 100° C. 4.65—5.13% H_2O.

Elementaranalysen.

I 0.3762 gr. lieferten 13.5 Cm^3 feuchten N_2 bei 27° und 746 ^{mm}.
II 0.4701 „ „ 17.6 „ „ „ „ 27°.5 und 725^{mm}.
III 0.3198 „ bei 100°-110° getrocknet gaben 0.3158 gr. und 0.7470 gr. CO_2, 0.1604 gr. H_2O und 0.0014 gr. Asche.
IV 0.3376 „ bei 100°-105° getrocknet gaben 0.3328 gr. und 0.7846 gr. CO_2, 0.1514 gr. H_2O und 0.0011 gr. Asche.

0.8896 gr. des Platindoppelsalzes, in lufttrocknem Zustande, ergaben bei mehrstündigem Trocknen bei 100°-105° 0.0281 gr. und weiter bei 110° im Ganzen 0.0310 gr. Gewichtsverlust und beim Glühen 0.1501 gr. Platin. Hieraus berechnet sich für das Platindoppelsalz 3.6% H_2O und 17.48% Pt. auf getrocknetes Salz. Dieser Platingehalt stimmt völlig mit dem von *Will* gefundenen 17.42-17.6% überein, weshalb ich auch später keine weiteren Bestimmungen ausgeführt habe. Weil die Analysen III und IV eine Differenz von etwa 0.6% H. ergaben, liess sich keine Formel mit Sicherheit aufstellen, wiewohl aus den Stickstoffbestimmungen schon hervorging, dass das Alkaloid nicht 12%, sondern nur etwa 4% Stickstoff enthielt.

Nach längerer Zeit gelang es mir, eine Quantität Chelidonin (A), c^a 10 Gr., aus Deutschland zu beziehen und haben wir damit noch weitere Analysen angestellt. Um zu erfahren, ob dieses, ein weisses Pulver bildendes, Alkaloid ein einheitlicher Körper sei, wurde es in mehrere Portionen getrennt und von jeder Analysen ausgeführt.

Es wurde dazu eine Portion mit Alkohol gekocht, wobei der grössere Teil zurückblieb (B). Mit der resultirenden alkoholischen Lösung wurde eine neue Portion des Alkaloides unter Zusatz von verdünnter Salzsäure und etwas Wasser gekocht. Hiedurch gingen grössere Quantitäten in Lösung und wurden daraus nach Verdünnung mit Wasser durch Natronlauge gefällt. Es bildete sich ein amorpher zusammenballender Niederschlag, der mit Aether ausgeschüttelt sich vollständig darin löste. Die abgetrennte ätherische Lösung wurde nach der Concentration durch Destilliren der freiwilligen Verdunstung überlassen und die sich abscheidenden grösseren Krystalle gesammelt (C).

Der beim Erwärmen mit verdünnter alkoholischer Salzsäure ungelöst

zurückgebliebene Anteil wurde durch Behandlung mit Alkohol und Essigsäure zum Teil in Lösung gebracht und daraus nach dem Verdünnen mit Wasser mit Kalilauge gefällt. Das gefällte Alkaloid wurde aus Chloroform umkrystallisirt und zur Entfernung von etwas gelbem Zersetzungs (Oxydations?) produkt durch Digestion mit Alkohol gereinigt (D).

Was endlich nach der Behandlung mit Alkohol und Essigsäure zurückgeblieben war und sich wie die übrigen Anteile qualitativ verhielt, wurde mit verdünnter Natronlauge macerirt, längere Zeit mit Wasser abgewaschen und zur Wasserbestimmung benutzt.

1.2150 gr. dieses lufttrocknen Alkaloides verloren nach einem Tage im Exsiccator 0.0002 gr., nach weiteren 2 Tagen fand keine weitere Gewichtsabnahme mehr statt, dann bei c^a 135° während mehrerer Stunden erhitzt und geschmolzen betrug die Gewichtsabnahme 0.0597 gr. und nach dem weiteren Erhitzen bis 140 à 145° im Ganzen 0.0614 gr., also 5.05% auf wasserhaltige, oder 5.23% auf getrocknete Substanz.

Elementar-Analysen. Einzelne wurden mit der entwässerten, andere mit der zum Teil entwässerten, die übrigen mit der lufttrocknen Substanz ausgeführt.

A. *ursprüngliches Chelidonin,*

V 0.2635 gr. verloren beim längeren Trocknen bei 100° 0.0009 gr., beim weiteren Trocknen bei 120°-130° noch 0.0118 gr. und lieferten: 0.6122 gr. CO_2 und 0.1240 gr. H_2O.

B. *nach teilweiser Lösung in Weingeist*

VI 0.3455 gr. bei 100° während 2 Stunden getrocknet verloren 0.0006 gr. und gaben 0.8062 gr. CO_2 und 0.1830 gr. H_2O.

VII 0.3924 gr. bei 130° während etwa 1 Stunde getrocknet verloren unter rothbräunlicher Färbung 0.0117 gr. und lieferten 0.9064 gr. CO_2 und 0.1931 gr. H_2O.

VIII 0.3500 gr. bei 130° während mehrerer Stunden erhitzt gaben unter Bräunung 0.0168 gr. = 4.8% Verlust. Von dieser getrockneten Substanz lieferten

0.2487 gr. nach dem Verbrennen

0.5980 gr. CO_2 und 0.1296 gr. H_2O.

IX 0.2619 gr. ungetrocknet gaben 10.4 Cm^3 feuchten N_2 bei 23° und 758^{mm}.

X 0.3713 gr. während 2 Stunden bei c^a 125° getrocknet verloren 4.3% an Gewicht und lieferten 14.3 Cm^3 feuchten N_2 bei 25° und 757^{mm}.

C. *aus Aether krystallisirt (siehe oben)*

XI 0.3130 gr. bei 100° während 3 Stunden getrocknet verloren an Gewicht 0.0016 gr. und ergaben 0.7285 gr. CO_2 und

0.1560 gr. H_2O.

XII 0.2491 gr. bei 120°-130° verloren 0.0098 gr. und gaben 8.55 Cm^3 feuchten N_2 bei 19° und 761.6^{mm}.

D. *aus Chloroform krystallisirt (siehe oben)*

XIII 0.3275 gr. ergaben 12.4 Cm^3 feuchten N_2 bei 22° und 758.3^{mm}.

1.4534 gr. gaben während 2 Stunden bei c^a 100° erwärmt 0.0100 gr., bei 135° geschmolzen noch 0.0496 und bei 160° im Ganzen 0.0719 gr. = 4.96% Gewichtsverlust. Von diesem getrocknetem Alkaloide lieferten

XIV 0.3901 gr. beim Verbrennen 0.1894 gr. H_2O(*)

Berechnen wir die Resultate der Analysen auf lufttrocknes Alkaloid, indem wir den Gewichtsverlust beim Trocknen als Wasser in Rechnung bringen, so finden wir in Procenten:

			Aus gr.	C.	H.	N.
1	Hier dargestelltes Chelidonin		0.3747	.....	.....	3.88
2	,,	,, ,,	0.3680	.....	.....	3.91
3	,,	,, ,,	0.3184	63.98	5.73	
4	,,	,, ,,	0.3367	63.59	5.16	
5	A	Chelidonin (Deutschland)	0.2635	63.4	5.76	
6	B	,, ,,	0.3455	63.64	5.91	
7	,,	,, ,,	0.3924	63.—	5.62	
8	,,	,, ,,	0.2612	62.44	6.04	
9	,,	,, ,,	0.2619	.....	.....	4.43
10	,,	,, ,,	0.3713	.....	.....	4.27
11	C	,, ,,	0.3130	63.5	5.60	
12	,,	,, ,,	0.2491	.....	.....	3.93
13	D	,, ,,	0.3275	.....	.....	4.24
14	,,	,, ,,	0.4094	.....	5.66	

Im Mittel ergiebt sich dann:

	Gefunden	Berechnet auf					
C = 12	63.36	C_{19}	63.84	C_{38}	63.86	C_{20}	64.7
H = 1	5.68	H_{19}	5.32	H_{40}	5.62	H_{21}	5.66
N = 14	4.09	N	3.92	N_2	3.92	N	3.77
O = 16	26.87	O_6	26.92	O_{12}	26.60	O_6	25.87

Aus der Uebereinstimmung der Analysen zeigte sich, dass das analysirte Chelidonin ein einheitlicher Körper war und der Gewichtsverlust beim Trocknen als Wasser betrachtet werden kann. Als Schmelzpunkt fand ich immer 135°—136° (uncorr.). Das bis 160° entwässerte Alkaloid wurde nach einigen

(*) Das CO_2 konnte nicht bestimmt werden, weil die Natronkalkröhre durch die starke Ausdehnung ihres Inhalts zersprang.

Tagen auf seinen Schmelzpunkt untersucht, es fing an bei c^a 110° zu erweichen, war aber erst bei 132°—135° zu einer durchscheinenden Flüssigkeit zusammengeschmolzen. Das Wasser wird nur sehr schwierig vollständig ausgetrieben, sogar bei Temperaturen über dem Schmelzpunkt. Bei den angeführten Elementaranalysen war der Gewichtsverlust bei 100°—105° ungefähr 0.2—0.7%, bei c^a 125° 3—4.4%. Bei völliger Entwässerung wurden gefunden 5.05 und 4.96%, während für die Formel $C_{19}H_{17}NO_5 . H_2O$ 5.04%, für $C_{20}H_{19}NO_5 . H_2O$. 4.85% Wasser verlangt werden.

Für das Platindoppelsalz:			Pt = 194.5	Pt = 197
I	$(C_{19}H_{19}NO_6 . HCl)^2 PtCl_4$	wird verlangt	17.3 %	17.5 %
II	$(C_{19}H_{17}NO_5 . HCl)^2 PtCl_4$	„ „	17.9 %	18.1 %
III	$(C_{20}H_{19}NO_5 . HCl)^2 PtCl_4$	„ „	17.43%	17.62%

während von Will 17.4—17.6, von mir 17.48%, gefunden wurde. Die zweite Formel würde hiernach nicht in Betracht kommen. Leider besass ich nicht weitere Substanz noch auch Verbrennungsröhren genug, um Analysen des Platindoppelsalzes auszuführen.

V. NANDINA DOMESTICA THUNB.[1]

Diese Berberidee ist in China[2] wie in Japan einheimisch und wird als Zierpflanze häufig cultivirt.[3] Sie erreicht eine Höhe von bis etwa 2 Meter. Den Blattern werden, wiewohl nicht giftige, doch emetische Eigenschaften zugeschrieben, und alle Teile dieser Pflanze finden in der Medicin Verwendung. Blätter wie Wurzelrinde werden in Form eines wässerigen Extraktes gebraucht. Sie sollen die Muskulatur stärken, geistige Thätigkeit erhöhen, heitere Gemütsstimmung herbeiführen, Schlaflosigkeit verursachen und das Leben verlängern, weiter rheumatische Affectionen heilen, sogar Gicht, auch Diarrhöe und Spermatorrhöe, die Gesichtsfarbe verschönern und Haare, selbst graugewordene, verstärken und schwärzen.

Auf Durchschnitt zeigt die Wurzel gelbe Farbe, von welcher ich vermutete, dass sie mit einem Berberingehalt zusammenhänge. Doch auch die weissen Teile der Wurzelrinde wie die Blätter schmecken ziemlich bitter und schien wahrscheinlich noch ein zweites Alkaloid vorhanden, wie auch in anderen berberinhaltigen Pflanzen farblose Alkaloide z. B. Oxyacanthin, Hydrastin aufgefunden sind. Eine vorläufige Untersuchung bestätigte dies und gelang es leicht, ein fast farbloses in Aether und Benzol lösliches Alkaloid abzuscheiden. Zur Erhaltung von etwas grösseren Quantitäten wurden mehrere Kilo's der Wurzelrinde[4] von Herrn Shimoyama in Arbeit genommen. Aus einer Portion wurde ein wässeriges Extrakt dargestellt (die Auszüge färbten sich beim Eindampfen schwarzbraun) und dieses wiederholt mit Weingeist ausgekocht. Nach dem Abdestilliren des Weingeistes wurde der Rückstand mit Wasser und Ammoniak versetzt, wobei sich ein harziger Niederschlag ausschied; dieser wurde mit Aether wiederholt ausgeschüttelt. Die abgetrennten ätherischen Lösungen lieferten nach der Destillation einen braunen amorphen Rückstand, welcher mit essigsäurehaltigem Wasser ausgezogen wurde. Nach Fällung mit Ammoniak wurde das immer noch gefärbte Alkaloid gereinigt durch Lösung in der erforderlichen Menge verdünnter Essigsäure, Zusatz von etwas Bleiacetat und Durchleiten von H_2S.;

(1). Jap. Nanten, 南天 der meist übliche Name.
Andere Namen sind:
Natsuten ナツテン, Nansoku 南燭, Nasjoku 南燭
Nansoboku 南草木, Rantensiku 南天竹
Nansjokuso 南燭草, Nantensjoku 南天燭
Nantensjokusidsu 南天燭目, Sannio 三葉, Uhanio 烏飯葉
Koku Uhansjo 黒飯樹, Tensiku 天竹, Tensikusishi 天竺枝子
Uso 鳥草, Taishun 大椿, Yotoso 揚桐草

(2). Auf dem Berge Kosan 高山, auch in der Provinz Toshiwa.

(3) Wegen der schönen Verteilung der Blätter, der rothen Farbe, welche sie nach der Blüthe annehmen, und des reichen, schönen, rothen Fruchtstands. Sie kommt auch mit weissen und hellvioletten Früchten vor. Sie wird benutzt als Zusatz zu Geschenken, aus Esswaren bestehend, und hat dann die Bedeutung, dass man sich nicht vor der Giftigkeit der Speisen zu fürchten hat, weil, falls dieselben auch giftig wären, die Nandina die giftigen Eigenschaften wegnehmen würde.

(4) Sie enthielt 37.65% H_2O, 1.17% Stickstoff und 3.37% Asche.

die farblose Lösung wurde dann partiell mit Ammoniak gefällt. Eine andere Portion der Wurzelrinde wurde in getrocknetem und grobgepulvertem Zustande mit Weingeist ausgezogen und nach dem Abdestilliren des Weingeistes dem Rückstande das Alkaloid durch Zusatz von Ammoniak und Ausschüttelung mit Aether entzogen. Der Aether hinterliess einen amorphen braunen Rückstand, worin sich nach längerer Zeit eine sehr geringe Krystallbildung zeigte. Diese Krystalle wurden so gut wie möglich aus dem übrigens braunen und amorphen Anteil entfernt, doch waren sie in zu kleiner Quantität anwesend, um weitere Reinigung und Untersuchung vorzunehmen. Das amorphe Alkaloid wurde wie früher mit Hülfe von Bleiacetat und H_2S gereinigt. Nur durch wiederholte Reinigung und mit ziemlichem Verlust konnten einige Gramm völlig weiss erhalten werden, die uns gestatteten es noch etwas näher zu untersuchen. In Uebereinstimmung mit dem japanischen Namen *Nanten* und dem daraus hergeleiteten Namen Nandina sei dem Alkaloide der Name Nandinin beigelegt.

Das *Nandinin* bildet ein amorphes, weisses Pulver, das namentlich in feuchtem Zustande, wie in Lösung Neigung zeigt, sich bräunlich zu färben, und dann nur durch wiederholte Reinigung und mit ziemlichem Verlust wieder weiss zu erhalten ist(†)

Es ist leicht in Weingeist, Aether, Benzol und Chloroform, wie in verdünnten Säuren löslich. Auf keine Weise konnten krystallisirte Salze dargestellt werden, weder durch freiwillige Verdunstung der neutralen Lösungen in Säuren, auch unter dem Exsiccator, noch durch Vermischen der ätherischen Lösung des Nandinins mit ätherischen Lösungen der Säuren u. s. w. Unter dem Mikroskope liess sich niemals eine Krystallisation beobachten. Auch beim langeren Verweilen einer Portion des Alkaloides über einem Uhrglas mit Salzsäure in einem verschlossenem Raum zeigte sich keine Krystallisation.

Die Lösung in verdünnter Säure wird von allgemeinen Alkaloidreagentien gefällt.

Alkalien geben weissen Niederschlag, in grossem Ueberschuss des Fällungsmittels löslich,

Hydrargyrichlorid weissen Niederschlag, in Salzsäure löslich,

Kaliumdichromat gelben Niederschlag,

Tannin weissen Niederschlag, in Ueberschuss, wie auch in verdünnter Essigsäure löslich. Salzsäure erzeugt in der Lösung in Tannin wieder einen Niederschlag, welcher von Neuem auf Zusatz von Tannin oder Essigsäure verschwindet, durch Salzsäure aber wieder hervortritt,

Mayers Reagens weissen Niederschlag, in Alkohol löslich,

Kaliumcadmiumjodid, *Kaliumwismuthjodid* fällen ebenfalls weiss.

Platinchlorid gelblich weissen Niederschlag,

Pikrinsäure gelben Niederschlag,

(†) Herr Shimoyama fand, dass Frösche bei subcutaner Injection von 1—3 mgr. des Nandinins getödtet werden.

Conc. Schwefelsäure löste mit violettlichrother Farbe. Auf Zusatz einer Spur Salpetersäure färbt sich die Lösung prachtvoll blau. Ebenso erzeugen andere Oxydationsmittel, wie Chlor- oder Bromwasser, Kalichromat, Ammonmolybdänat, auch Ferrichlorid in dieser schwefelsauren Lösung grünblaue bis blaue Färbung. Auch mit Selensäure oder Tellursäure wird diese Lösung parchtvoll grün, später indigblau Das Platindoppelsalz wird ebenfalls von H_2SO_4 prachtvoll blau gefärbt.

Chlor- oder Bromwasser färben grün,

Salpetersäure grasgrün, nachher braun.

Elementaranalysen.

I 0.2990 gr. des lufttrocknen Alkaloides, bei 100—105° getrocknet gaben 0.2943 gr. Trockensubstanz und nach dem Verbrennen 0.1566 gr. H_2O und 0.7473 gr. CO_2

II 0.3133 gr. lieferten nach dem Trocknen bei 105°, 0.3091 gr. und beim Verbrennen 0.1658 gr. H_2O und 0.7877 gr. CO_2

III 0.3072 gr. des bei 100° getrockneten Alkaloides lieferten 11.9 cm^3 feuchten N_2 bei 11° und 707.8^{mm}.

oder in Procenten:

	I	II	III	Mittel	Berechnet auf $C_{19}H_{19}NO_4$
C = 12	69.2	69.5	——	69.35	70.17
H = 1	5.96	5.94	——	5.95	5.84
N = 14	——	——	4.28	4.28	4.31
O = 16	——	——	——	20.42	19.68

1.004 gr. des lufttrocknen Platindoppelsalzes verloren nach einigen Tagen im Exsiccator 0.0128 gr. und nachher bis zu constantem Gewicht bei 105° getrocknet noch 0.0398 gr. und lieferten beim Glühen 0.1716 gr. = 18.23% Platin, auf getrocknetes Salz berechnet.

Das Salz $(C_{19}H_{19}NO_4 . HCl)^2 PtCl_4$ verlangt 18.35% Pt. (Pt = 194.5)

Nach obiger Formel würde das Nandinin mit Hydroberberin $C_{20}N_{21}NO_4$ homolog sein.

Das Berberin liess sich aus den mit Wasser oder Weingeist dargestellten Auszügen nicht in befriedigender Weise durch Stehenlassen mit Salzäure erhalten. Es wurde aber in genügender Menge abgeschieden, um seine Anwesenheit festzustellen, als die mit Ammoniak versetzte und mit Aether wiederholt ausgeschüttelte Flüssigkeit nach dem Alkalischmachen mit Chloroform ausgeschüttelt wurde. Aus dem Rückstande konnte durch Versetzen mit verdünnter Schwefelsäure, Umkrystalisation der ausgeschiedenen Krystalle aus Alkohol und weitere Reinigung durch Fällung der wässerigen Lösung mit verdünnter Schwefelsäure eine kleine Menge reiner, gelber Krystalle erhalten werden, die ganz das Aussehen von Berberinsulphat zeigten und auch in ihren Reaktionen damit übereinstimmten.

VI. ORIXA JAPONICA THUNB.

Ueber diese einheimische, auf hohen Bergen vorkommende Rutacee findet sich in der japanischen Litteratur Folgendes. Das Wurzel- und Stammholz und die Blätter dieses etwa 10 Fuss hohen, im Frühling blühenden Baumes werden in Japan, wie in China als Heilmittel bei Typhus, Frost- und Wechselfieber, Malaria, Speichelfluss benutzt.(*) Sie sollen auch Geschwulste in der Halsgegend beseitigen und bei Insectenstichen und Schlangenbiss Verwendung finden. Der chinesische Name Siyousan 常山 ist der übliche für die Wurzeldroge, Siyokuschizu 蜀漆 der für die Pflanze.

Japanische Namen sind Kokusagi コクサギ, Nogusa ノグサ Heminotiya ヘミノチヤ, Haneboku ハネボク, Tomome トモメ, Tiyabisiyaku チヤビシヤギ u. s. w. Die Wurzel soll verfälscht werden mit der des Clerodendron trichotomum (Kusagi クサギ) oder der Hydrangea hirta Sieb. (Yama asisai ヤマアジサイ). Was im Handel Kaisiyu-Siyousan (海州常山) heisst, ist die Wurzel von Clerodendron trichotomum.

Wurzel- und Stammholz wurden einer vorläufigen Untersuchung unterworfen, besonders zur Feststellung, ob die gelbe Farbe, welche beide besitzen, auch hier mit einem Gehalt an Berberin zusammenhänge. Herr Tamba extrahirte dazu eine ziemliche Menge des groben Pulvers durch Perkoliren mit Weingeist, destillirte den Weingeist vom Perkolate ab und behandelte den Rückstand mit Wasser. Es schied sich dabei ein gelbbraunes Harz ab, welches abfiltrirt wurde. Das eingeengte Filtrat lieferte nach längerem Stehen mit Salzsäure eine ziemliche Menge gelbe Krystalle. Diese wurden gesammelt und durch Umkrystallisation aus Alkohol oder Wasser oder durch Fällung der wässerigen Lösung mit verdünnter Salzsäure gereinigt.

Mit salzsaurem Berberin verglichen zeigten sich die gereinigten Krystalle qualitativ völlig damit identisch.

Das Harz, welches wiederholte Male durch Lösen in Alkohol und Fällung durch viel Wasser unter Zusatz von etwas Salzsäure gereinigt wurde, bildete ein graulich gelbes Pulver. Es ist geschmack- und geruchlos, unlöslich in Wasser, leicht löslich in Alkohol und Alkalien, unlöslich in Aether.

(*) Verschiedene Recepte werden empfohlen. Das Holz wie die Blätter werden z. B. mit Glycyrrhizae radix zusammen gedämpft an der Sonne getrocknet und während einer Nacht in Sake macerirt, nach dem Coliren wieder an der Sonne getrocknet, dann geröstet und zerstossen. Auch wird Siyusan mit Essig zubereitet und besitzt das Praeparat dann eine brechenerregende Nebenwirkung. Auch wird eine Abkochung (15 : 250) mit Reiswasser bei Fieberanfall auf einmal genommen, um Erbrechen zu erregen. Ohkin erwähnt in seiner Gesundheitslehre, dass er 40 Jahre lang ausgezeichnete Wirkung dabei gesehen hat.

VII. SKIMMIA JAPONICA THUNB.

Diese Rutacee ist eine zu den einheimischen Giftpflanzen gehörende Staude, welche überall in Japan vorkommt. Der japanische Name ist *Miyama Sikimi* ミヤマシキミ (chin. In-wu 茵芋)(1). Der Flora Japonica v. Siebold ist Folgendes entnommen: Die Pflanze(2) kommt überall in den Wäldern an schattigen Orten auf Bergen vor (Fundort Nagasaki auf dem Berge Kawara, c^a 600 Meter); Höhe 3-4 Fuss mit nach dem Boden geneigten Zweigen, in cultivirtem Zustande erreicht sie eine grössere Höhe. Die Blüthen erscheinen im März-April und verbreiten, namentlich Abends, einen angenehmen an Daphne odora erinnernden Geruch. Die Früchte sind roth oder bei einer cultivirten Varietät weiss und reifen im October. Die Blätter schmecken aromatisch und scharf. Die Pflanze wird allgemein in Gärten und bei Tempeln cultivirt und wegen ihrer schönen Inflorescenz, des angenehmen Geruchs ihrer Blüthen und schönen, rothen Früchte als Zierpflanze angewendet. Die Japaner und Chinesen zählen sie zu den Giftpflanzen (sikimi=böse Frucht).

Durch die freundlichen Bemühungen des Herrn Shimoyama gelang es mir, eine grosse Quantität der im Frühjahr (Jan.) in der Provinz Boshiu in schattigen Thälern des Berges Kiyosumi yama gesammelten Pflanzen zu erhalten.

Aus den frischen Blättern wurden durch Dampfdestillation etwa 50-70 gr. des ätherischen Oels dargestellt. Dieses war klar, fast farblos, sehr schwach gelblich gefärbt und von eigenartigem Geruche, etwas an das ätherische Oel von Citrus bigaradiae und Juniperusarten erinnerend. Es hatte ein spec. Gew.

(1) Andere Namen sind:
Sinsan, it. Portugalnoki (Thunberg. Flora Jap. p. 62), Haharagusa (Honzohiyuhumebiko wakunsjo), Yamarincho (Honzokoi)

(2) Frutex tri-quadripedalis (nunquam, ut voluit Kaempferus, arbor vasta) ramis in planta spontanea plerumque deflexis, in culta erectis vel patentibus strictis alternis teretibus, cortice glabro glanduloso-verruculoso sordide e cinereo flavescente vel fuscescente valde aromatico vestitis, novellis virentibus. Folia alterna, quatuor ad sex e quavis gemma, per tres annos persistentia, cujusvis anni fasciculato- approximata et ab iis anni praecedentis remota, petiolata petiolis semiteretibus crassiusculis glabris basi articulatis semipollicaribus; lamina obovata-oblonga vel oblonga, utrinque attennata, basi non articulata, acuta, integerrima, coriacea, penninervia, nervo medio subtus valde prominente, lateralibus in planta viva vix conspicuis, utrinque glabra et laete viridis vel rarius subtus verruculis prominulis adspersa et fuscescens, 4-6 pollices longa, 15-20 lineas lata. Stipulae nullae. Gemmae perulatae; Perulae imbricatae, lanceolatae, acutae, foliaceae, post vernationem longe a se invicem remotae, eo modo ut rami hornotini magis inter perulas distantes quam inter folia approximata et fasciculata extendantur indeque a basi ad duas tertias longitudinis aphylli et perularum delapsarum cicatricibus tantum sint notati. Flores ex apice ramorum, in paniculam bi-vel tripollicarem densam thyrsoideam et subpyramidatam dispositi, polygami, suaveolentes, vernales. Rachis paniculae stricte erecta, teres, glabra, albida, rami primarii alterni, patentes, singuli Bractea lanceolata vel lineari-lanceolata acuta coriacea tandem decidua suffulti; secundarii subdichotomi, bracteolati; Pedunculi uniflori, florem subaquaentes vel es longiores, teretes, sursum clavato- incrassati. Calyx hypogynus, gamosepalus, brevis, urceolatus, quadri- quinquefidus, persistens; limbi laciniae ovato semiorbiculares, acutiusculae vel obtusae, integerrimae, erecto- patentes, glabrae, albae, aestivatione imbricatae. Corolla hypogyna, tetra- vel pentapetala, decidua; Petala cum calycis laciniis alternantia, sessilia ovato-

von 0.8633 bei 20°, war löslich in Weingeist und Essigsäure mit schwacher Opalescenz, verpuffte mit Jod und wurde von Schwefelsäure röthlichbraun gefärbt. Mit Natrumbisulfitlösung öfters geschüttelt, schied sich erst nach einigen Wochen ein wenig einer butterähnlichen Masse ab. Mit Kali geschüttelt fand keine merkbare Volumabnahme statt; beide Schichten wurden bräunlich gefärbt, auf Zusatz von ammoniakaler Silberlösung fand aber nur schwache Reduction statt.

Im Soleil- Ventzke's Polarisations Apparat zeigte es p. 1 Dcm. eine Rechtsdrehung von +7°.45. Der wiederholten fractionirten Destillation unterworfen destillirte von den flüchtigeren Anteilen der grössere Teil zwischen 170°-173° (uncorr.), von dem Reste ging der grössere Teil zwischen 225° und 235° (uncorr.) über.

Die niedrigst siedenden Fractionen waren farblos, wurden von Schwefelsäure orangeroth, von trocknem Salzsäuregas violettlichrothbraun gefärbt, an der Luft verdickten sie sich allmählich.

0.2655 gr. des Destillates 170°-178° gaben bei Verbrennung 0.2769 gr. H_2O und 0.8436 gr. CO_2

oder in Procenten:

	Versuch	$C_{10}H_{16}$
C = 12	86,7	88.2
H = 1	11.6	11.8
O = 16	1.7	0.—

Die höher siedenden Fractionen waren schwach grün- bis gelblich gefärbt. Von dem Destillate 225°-235° lieferten

0.3872 gr. 0.3754 gr. H_2O und 1,1018 gr. CO_2

oblonga vel oblonga, acutiuscula, integerrima, crassiuscula, superne parum concava et sulco longitudinali exarata, alba, subtus convexiuscula, alba marginem versus roseo-suffusa, crassiuscula, inter se aequalia, calyce triplo longiora, aestivatione imbricata. Stamina tot quot petala et cum his alternantia, hypogyna, extra torum affixa, in floribus foemineis abortiva, ovario breviora; Filamenta inter se libera, subulata, erecta, glabra, alba, petalis parum longiora; Antherae dorso parum supra basin affixae, ovatae, obtusae, basi cordatae, quadriloculares et antice longitudinaliter quadrivalves: Torus in floribus masculis quadrilobus, lobis brevibus transverse ellipticis carnosis cum staminibus alternantibus, in hermaphroditis et foemineis annulus, brevissimus basin ovarii arcte cingens, virescens. Ovarium superum, liberum, toro cinctum, ovato- globosum, glabrum, plerumque quadriloculare: locula uniovulata, ovulo ex angulo centrali pendulo anatropo ovata. Rudimentum ovarii in flore masculo subconicum, breviter apiculatum. Stylus simplex, erectus, quadrisulcatus, crassus, ovario et staminibus brevior, glaber. Stigma capitato- incrassatum, quadri- vel quinquelobum, lobis abbreviatis convexis superne papillosis et sulco tenui exaratis, glabrum, virens. Drupa supera, globosa vel obsolete quadri- vel quinqueloba, magnitudine pisi, glabra, coccineo- rubra; sarcocarpium carnosum glandulis immersis obsitum, tandem siccum, septis tenuibus membranaceis: endocarpium in cocces quatuor vel quinque apice affixos ceterum a sarcocarpio solutos cartilagineos siccos indehiscentes trigonos utrinque attenuatos dorso convesos lateribus planos glabros monospermos mutatum. Semen unicum in quovis cocco, ex angulo centrali pendulum, ellipticum dorso convexum, lateribus planis angulis acutis, glabrum, Testa membranacea, in angulo centrali raphe notata lineari ab hilo elliptico in chalazam usque, verticem seminis occupantem, producta. Tunica interior tenuissima, a testa vix separanda, fusca. Albumen carnosum, aequabile. Embryo orthotropus, radicula brevissima hilum spectante, cotyledonibus magnis carnosis late ellipticis utrinque rotundatis plane sibi impositis et hinc simul parum concavis, plumula inconspicua. (*v. Sieb.* Flor. Jap.)

oder in Procenten.

	Versuch	$C_{10}H_{16}O$
C = 12	77.6	78.9
H = 1	10.7	10.55
O = 16	11.7	10.55

Die in dem Destillationsgefässe zurückbleibenden (oberhalb 250° siedenden) Anteile wurden beim Erkalten fest, waren in Weingeist, Wasser, Petroleumäther und Essigsäure nicht oder kaum, leicht dagegen in Chloroform löslich. Die Resultate dieser Analysen, wiewohl nur je einmal ausgeführt, zeigen an, dass ausser einem Terpen (*Skimmen*) vielleicht eine Kamferart vorliegt. Das in Ol. rutae vorkommende *Methylnonylketon* verlangt 77.65% C, 12.94% H und 9.41% O. Ein Terpenhydrat $C_{10}H_{18}O$ würde 77.9% C, 11.7% H und 10.4% O verlangen. Der Kohlenwasserstoff kann weder *Nonylhydrür* C_9H_{20} noch *Nonylen* C_9H_{18} sein. Ersteres enthält berechnet 15.6% H, letzteres 14.3% H. Eine Dampfdichtebestimmung konnte ist bis jetzt nicht ausführen.

Aus einer gesonderten Portion des Holzes mit Rinde wurde ein weingeistiges Extrakt dargestellt, und es gelang mir leicht, durch vorläufige Versuche einen krystallinischen Körper daraus abzuscheiden, welchen ich in grösserer Menge dargestellt und auch noch etwas weiter untersucht habe.

Schon durch Erwärmen des Extraktes mit einer geringen Menge Wasser lässt es sich in eine dunkelschwarzgrüne harzige und eine obere sirupöse braune Masse trennen. Letztere liefert nach längerem Stehen in geeigneter Concentration einen erheblichen krystallinischen Bodensatz, welcher durch Umkrystallisation aus verdünntem Weingeist und Wasser mit Hülfe von Tierkohle völlig weisse Krystallnadeln liefert.

Skimmin. Weisse Krystallnadeln, wenig in kaltem, leicht in heissem Wasser und Weingeist löslich, sehr wenigin Aether und Chloroform, leicht in Alkalien mit schön blauer Fluorescenz löslich. Die wässerige und alkoholische Lösung fluoresciren nicht und schmecken bitter. Schmelzpunkt 210° (uncorr.). Es scheint nicht giftig zu sein: 0.100 gr., in c^a 5-6 Cm^3 warmem Wasser mit 2 Tropfen Natronlauge einem Hunde subcutan injicirt, verursachten keine besonderen Symptome ausser etwas Lustlosigkeit.

Mit Bleisubacetat (Bleiacetat + NH_3) entsteht weisse Fällung.

Die wässerige Lösung reagirt neutral, reducirt in der Siedehitze alkalische Kupferlösung nicht und wird von den gewöhnlichen Metallsalzen, auch Bleiacetat, Ferrosulfat, Eisenchlorid und Goldchlorid, weder gefällt noch verändert. Sowohl von dem im Exsiccator getrockneten als dem bei höherer Temperatur entwässerten *Skimmin* führte ich Elementaranalysen aus. Im Exsiccator verlor das lufttrockne Skimmin 0.5% und weiter bei 130°-135° 3.96-4.2 proc. Wasser.

I 0.2906 gr. des entwässerten Skimmins lieferten
0.1319 gr. H_2O und 0.5857 gr. CO_2

II 0.3150 gr. des entwässerten Skimmins lieferten
0.1328 gr. H_2O und 0.6287 gr. CO_2

III 0.3534 gr. des während mehrerer Tage im Exsiccator getrockneten Skimmins gaben 0.1597 gr. H_2O und 0.6860 gr. CO_2

IV 0.3274 gr. des im Exsiccator getrockneten Skimmins gaben 0.1432 gr. H_2O und 0.6382 gr. CO_2

oder in Procenten, auf wasserfreie Substanz berechnet.(*)

	I	II	III	IV	Mittel	Berechnet auf $C_{15}H_{16}O_5$
C = 12	55.0	54.4	55.3	55.5	55.—	55.5
H = 1	5.0	4.7	4.8	4.6	4.8	4.9
O = 16	40	40.9	39.9	39.9	40.2	39.5

Beim Kochen mit verdünnten Mineralsäuren scheidet sich ein in Wasser unlöslicher krystallinischer Körper (*Skimmetin*) ab, während das Filtrat starke Reduction gegenüber alkalischer Kupferlösung zeigt.

5.938 gr. mit 35 Cm^3 verdünnter Schwefelsäure (1 : 25) gekocht, bis Lösung stattfand, und in geschlossenem Kolben dann mehrere (6) Stunden auf dem Wasserbade erhitzt gaben nach dem völligen Erkalten abfiltrirt und ausgewaschen 2.783 gr. = 46.8% Skimmetin.

10 Cm^3 des Filtrates (100 Cm^3) bis 50 Cm^3 verdünnt wurden mit *Fehling*'s Lösung titrirt. Im Mittel wurden für 10 Cm^3 Kupferlösung 8.2 Cm^3 verbraucht, woraus sich 51.35% Glucose auf lufttrocknes Skimmin berechnet.

80 Cm^3 des Filtrates wurden mit Baryumcarbonat behandelt und lieferten nach dem Trocknen bei 110° 2.527 gr. = 53.2% einer braungelben sirupösen Substanz, welche in Wasser (c^a 20 Cm^3) bis auf 0.039 gr. = 0.8% löslich war. Bringen wir diese 0.8% als *Skimmetin* in Rechnung, so ergiebt sich aus 100 Teilen *Skimmin* 47.6 Teile *Skimmetin* und 52.4 (titrirt 51.35%) Glucose. Das lufttrockne Glucosid scheint daher bei seiner Spaltung kein weiteres Wasser aufzunehmen.

Das glucoseähnliche Spaltungsprodukt wurde in Wasser gelöst und die Lösung mit Tierkohle entfärbt; die filtrirte Lösung enthielt, durch Wägung bestimmt 7.16%, durch Titration 7.2% Glucose. 1 dm dieser Lösung im *Soleil-Ventzke's* Polarisator zeigte eine Drehung von + 5.2(†), woraus sich ein spec. Drehungsvermögen berechnet von

$$[a] = \frac{5.2.100}{d\ 7.16} \cdot 0.346 = \frac{25.1}{d} = \frac{25.1}{1.026} = +\ 24.5(‡).$$

also etwa die Hälfte von dem der Dextrose (58.7 bei 20°, *Tollens*) (möglich durch Glucosangehalt).

Skimmetin. Farblose Krystallnadeln, welche in kaltem Wasser fast völlig unlöslich, in kochendem etwas besser löslich sind; auch löslich in Weingeist,

(*) III und IV sind mit einer gesondert dargestellten und gereinigten Probe angestellt.

(†) bei Petroleumlicht.

(‡) d = 1.026 (spec. Gew. einer 7.2% Zuckerlösung).

Aether, Chloroform und Eisessig. In verdünnten Alkalien löst es sich leicht, ohne die alkalische Reaction abzustumpfen. Die wässerige, weingeistige und alkalische Lösung fluorescirt schön blau. Auch conc. Schwefelsäure löst es mit intensiver blauer Fluorescenz. Es reducirt auch beim Kochen alkalische Kupferlösung *nicht*. Die wässerige Lösung wird von Bleiacetat gefällt, der Niederschlag ist in Weingeist löslich. Auch wird die warm gesättigte wässerige Lösung von Ferrichlorid blau gefärbt, von $AuCl_3$ rosa, später violett und blau. Für die Löslichkeit in Wasser fand ich bei 11° 0.022%, bei 23° 0.03% und für den Schmelzpunkt 223° (uncorr.) Bei stärkerer Erhitzung entsteht ein krystallinisches Sublimat, und es verflüchtigt, ohne eine Spur Asche zu hinterlassen. Cumaringeruch konnte ich bei der Verflüchtigung nicht bemerken.

Elementaranalysen von der bei 110° getrockneten Substanz, wobei sie kein Krystallwasser verlor.

0.3120 gr. lieferten 0.1068 gr. H_2O und 0.7632 gr. CO_2
0.3143 „ „ 0.1011 „ H_2O „ 0.7738 „ „

Von einer anderen Probe, aus einer gesondert dargestellten Portion Skimmin erhalten und zuletzt aus der alkalischen Lösung mit Salzsäure gefällt, lieferten

0.2943 gr. 0.1000 gr. H_2O und 0.7155 gr. CO_2.

oder in Procenten:

	I	II	III	Mittel	Berechnet auf $C_9 H_6 O_3$
C = 12	66.7	67.1	66.3	66.7	66.67
H = 1	3.8	3.57	3.78	3.71	3.7
O = 16	29.5	29.33	29.92	29.59	29.63

Die Spaltung des Skimmins kann durch die Gleichung,

$$\underset{\text{Skimmin}}{C_{15} H_{16} O_8 . H_2O} = \underset{\text{Glucoseart}}{C_6 H_{12} O_6} + \underset{\text{Skimmetin}}{C_9 H_6 O_3}$$

ausgedrückt werden.

Das wasserhaltige Glucosid würde nach dieser Gleichung 47.3% *Skimmetin* und 52.7% Glucose liefern, während ich fand 47.6% Skimmetin und 52.42% Glucose.

Die Formel $C_{15} H_{16} O_8 . H_2O$ verlangt 5.26% Wasser, während ich fand für das unter dem Exsiccator getrocknete Skimmin 3.92-4.2%. Im Exsiccator verlor es bei einer Bestimmung 0.5%, also im Ganzen 4.42-4.7%. Warscheinlich war das analysirte lufttrockne Skimmin schon etwas verwittert.

Das *Skimmin* und *Skimmetin* zeigen mit dem *Scopolin* und *Scopoletin* grosse Uebereinstimmung. Sie unterscheiden sich von einander z. B. durch Folgendes.

		Schmpt.	Mit Ammoniak
Skimmin	schwieriger löslich in kaltem Wasser	210°	gelbe Lösung und grünblauer Reflex
Scopolin	leichter „ „ „ „	217°	farblose „ „ blauer „
Skimmetin	reducirt nicht alkalische Kupferlösung	223°	67.% C und 3.7% H
Scopoletin	„ stark „ „	193°	61.% C und 4.2% H

Bei dem Vergleich mit anderen Glucosiden zeigen sie sich nahe mit *Aesculin* und *Daphnin* verwandt, und, was das *Skimmetin* anbetrifft, scheint es mit *Umbelliferon* identisch. Es ist dies um so interessanter als aus Daphnearten— deren Blüthe denselben Geruch wie Skimmia Japonica zeigen—das *Umbelliferon* durch trockne Destillation des *Daphnins* oder des Extraktes entsteht. Das *Daphnin* $C_{15}\ H_{16}\ O_9$ und das damit isomere *Aesculin* liefern bei ihrer Spaltung durch Säuren *Oxyumbelliferon*, $C_9\ H_6\ O_4$ (*Daphnetin* und *Aesculetin*).

In der nächsten Tabelle habe ich zum Vergleich mit *Scopolin* und *Skimmin* einige Eigenschaften dieser Körper übersichtlich zusammengestellt, so weit die mir zugänliche Litteratur reichte.

Das *Skimmetin*, wofür genau die procentische Zusammensetzung gefunden wurde, welche der Formel des Umbelliferons

$$C_6H_3\ O \begin{cases} CH : CH.\ CO \\ OH \end{cases}$$

entspricht und dessen Schmelzpunkt (223° uncorr.) auch mit dem des von *Tiemann* und *Reimer* für Umbelliferon festgestellten Schmelzpunkt (223°—224°) übereinstimmt, dürfte wohl auch wegen der völlig analogen Fluorescenzerscheinungen als identisch mit Umbelliferon angesehen werden und in dem *Skimmin* deshalb das Glucosid dieses inneren Anhydrides der Umbellasäure vorliegen.

Auch das *Scopoletin* scheint mir nach seinen Eigenschaften sehr nahe mit den Zimmtsäurederivaten Aesculin, Kaffeesäure, Ferulasäuren, Umbelliferon etc. zusammenzuhangen. Eine Identität mit Aesculetin (Schpt. über 270°) und Daphnetin (Schpt 253.—256°) kann nicht vorliegen wegen der Differenzen der Schmelzpunkte. Auch enthält das Scopoletin mehr H. Vielleicht dass bei näherer Untersuchung sich die Formel $C_{10}\ H_8\ O_4$ (=Methyläsculetin) für das Scopoletin bewährt und dann die Spaltung des Glucosides nach folgender Gleichung stattfindet.

$$2\ C_{24}\ H_{30}\ O_{15} = 3\ C_6\ H_{12}\ O_6 + 3\ C_{10}\ H_8\ O_4 \text{ oder}$$
$$C_{16}\ H_{20}\ O_{10} = \quad C_6\ H_{12}\ O_6 + \quad C_{10}\ H_8\ O_4$$

Es würde dabei 48.3% Glucose entstehen müssen, womit die letzt angeführte Bestimmung durch Titration (Seite 24.—0.313 gr. Glucose aus 0.6498 gr. Scopolin = 48.1%) in Einklang steht.

Das von *Tiemann* und *W. Will* dargestellte *Monomethyläsculetin* $C_9\ H_5\ O_3 . OCH_3$ hat den Schmelzpunkt 184°. und wird von $Fe_2\ Cl_6$ nicht gefärbt, das Dioxy *β. Methylcumarin* $C_6\ H_2\ O \begin{cases} (OH)_2 \\ C\ (CH_3) : CH.\ CO \end{cases}$ von *H. V. Pechmann* und *C. Duisberg* schmilzt bei 235°, die Lösung in conc. Schwefelsäure fluorescirt nicht.

Würde sich das *Scopoletin* als Cumarinderivat herausstellen, so wären in der Scopolia Japonica Körper mit den beiden Kohlenstoffkernen

$$C_6 . C < \overset{C}{C} \quad \text{und} \quad C_6 . C : C . C$$

vertreten, ersterer als Tropasäure in dem Alkaloide (*Scopolein*), letzterer in dem (*Scopoletin*), und *Scopolin*.

Was die anderen Bestandteile der *Skimmia Japonica* anbetrifft, so kann ich darüber vorläufig nur noch Folgendes mitteilen: Das *Skimmetin* wurde auch als solches aus der Pflanze mit dem Schmelzpunkte 222°-223° (uncorr.) abgeschieden, war aber schwierig von mehreren amorphen, zum Teil harzigen Körper zu trennen. Weiter erhielt ich einen weissen krystallisirten Körper, welcher bei c. 244° (uncorr.) schmolz, in Wasser nicht, sehr wenig in Weingeit, besser in Petroleumäther, Aether, leichter in Chloroform und auch in Essigsäure löslich. In Alkalien löst es sich nicht und zeigt keine Fluorescenzerscheinungen. Die Lösung in Essigsäure gibt mit H_2SO_4 Braunfärbung. Das Gift wurde bis jetzt als eine bräunliche, amorphe Substanz erhalten. Sie ist wenig in kaltem, ziemlich in kochendem Wasser, leicht in Weingeist, Aether und Chloroform löslich. Einige Milligramm. in 1 Cm^3 Wasser gelöst töten Frösche unter fast völliger Lähmung.

Aesc

Dap

Sco

Ski

Aes

C_6 H

Dap

Sc

Sk

U

M

D

	Wasserfrei.			Schmelzpunkt.	Alkalische Kupfer-Lösung.	Fe_2Cl_6	$AuCl_3$.	Lösung in Wasser.	H_2SO_4	Lösung in Alkalien.	Feuchte NH_3-Atmosphäre.
	Proc. C	Proc. H	Proc. O								
Aesculin. $C_{15}H_{16}O_9 . 2H_2O$	52.9	4.7	42.4	160°	reducirt.	nicht.	grünblau, beim Erwärmen Goldausscheidung.	starke blaue Fluorescenz, noch in einer Lösung von 1 : 1.500.000	——	gelb mit blauer Fluorescenz	goldgelb.
Daphnin.				200°	reducirt nach längerem Kochen.	blau. (?)	——	——	——	goldgelb.	——
Scopolin $C_{24}H_{30}O_{15} . 2H_2O$ ($C_{16}H_{20}O_{10}$)	50.6	5.4	44.–	217°	nicht.	nichts, beim Erwärmen braungelb.	nichts, beim Kochen Goldausscheidung.	farblos, fluorescirt nicht.	wird gelb und löst sich fast farblos mit schwach blauem Reflex.	schwach gelb.	farblos, nach mehreren Tagen bläu bis grün.
Skimmin $C_{15}H_{16}O_8 . H_2O$	55.–	4.8	40.2	210°	nicht.	nichts, beim Erwärmen braungelb.	nichts, kann mit $AuCl_3$ gekocht werden ohne Färbung und Goldabscheidung.	farblos, fluorescirt nicht.	löst sich farblos mit schwach violettblauem Reflex.	farblos,	farblos, nach mehreren Tagen schön grünblau.
Aesculetin. C_6H_2O(CH:CH C.O)(OH)(OH) Oxyumbelliferon. $C_9H_6O_4$ Dioxycumarin.	60.6	3.36	36.04	über 270°	reducirt.	grünblaue Lösung mit Alkali roth, durch Säure wieder blau.	in der warmen gesättigten Lösung Rothbraunfärbung, bald Au Ausscheidung.	kalt gesättigt farblos mit schwachem blauen Reflex.	schwach gelblich mit schwach blauer Fluorescenz.	intensiv gelb mit schwacher Fluorescenz.	fleischfarbig, wie Mangansulphid.
Daphnetin.				253°—256°	reducirt.	grün mit Alkali roth.	——	gelb.	gelb.	orange.	——
Scopoletin $C_{12}H_{10}O_5$ ($C_{10}H_8O_4$)	61.1	4.2	35.7	198°	reducirt.	dunkel bläulichgrüner Niederschlag.	blau, beim Kochen grüner und grauschwarzer flockiger Niederschlag.	farblos mit blauer Fluorescenz.	gelb mit blauer Fluorescenz.	goldgelb, mit Weingeist verdünnt grünlichgelb und mit starkem blauen Reflex.	goldgelb.
Skimmetin $C_9H_6O_3$	66.7	3.7	29.6	223°	nicht.	bläulich.	beim Erhitzen rosa, später violett und blau.	farblos mit blauer Fluorescenz.	farblos mit stark blauer Fluorescenz.	goldgelb, mit Weingeist verdünnt fast farblos mit starker blauer Fluorescenz.	farblos, nachher schwach braun.
Umbelliferon $C_9H_6O_3$ C_6H_3(CH:CH. CO)(O)(OH)	66.67	3.7	29.63	223°–224°	——	——	——	farblos mit blauer Fluorescenz.	blaue Fluorescenz	——	——
Monomethyläsculetin C_6H_2(CH:CH. CO)(O)(O CH_3)(OH) $C_{10}H_8O_4$	62.5	4.17	33.33	184°		keine Färbung.					
Dioxy β Methylcumarin C_6H_2(C. (CH_3): CH. CO)(O)(OH)(OH)				235°		intensiv grüne Färbung.		fluorescirt nicht.	gelb.		

ANHANG.

Andromeda Japonica Th.

Nachdem ich die Untersuchung der *Andromeda Japonica* beendet hatte(*) erschienen aus dem Laboratorium von Prof. *Dragendorff* ausführliche Mitteilungen von *R. Thal* under den Titel: *Erneute Untersuchungen über die Zusammensetzung und Spaltungsprodukte des Ericolins* und *seine Verbreitung in der Familie der Ericaceen nebst einem Anhang über die Leditannsäure, die Callutannsäure und das Pinipikrin.* (Pharm. Zeitschr. f. Russland Jg. XXII, 1883, No 14-18).

Wiewohl keine Andromeda's in den Kreis seiner Untersuchungen aufgenommen wurden, scheinen mir dieselben sich so nahe an den von mir mit der *A. Japonica* angestellten anzuschliessen, dass ich es erwünscht erachte, hier ein kurzes Referat über diese Untersuchungen von *Thal* einzuschalten.

T. stellte das zu seine Versuchen dienende Ericolin, aus 300 lb. zerhacktem *Ledumkrautes* dar durch Fällung des wässerigen Infuses mit Bleiacetat und Bleiessig. Das Filtrat wurde eingedampft, nochmals filtrirt und mit H_2S entbleit. Nach dem Filtriren wurde bis zur Extraktconsistenz eingeengt. Das Extrakt wurde wiederholt mit einem Gemische von wasserfreiem Aether und Alkohol (1 : 2) ausgekocht, der Aetheralkohol abdestillirt und der Rückstand wiederholt diesem Ausziehungsverfahren unterworfen, bis er sich in dem genannten Lösungsmittel völlig löste.

Das so erhaltene Präparat wurde einige Stunden lang bei 95°-100° C getrocknet und dann über H_2SO_4 im Vacuum gehalten. Es besass nun *Extraktconsistenz* und enthielt 0.36% Asche. Als solches der Elementaranalyse unterworfen, während der Feuchtigkeitsgehalt in besonderen Proben bei 95°-100° C bestimmt wurde, ergab es im Mittel aus 3 ziemlich übereinstimmenden Anlysen und auf trockne, aschefreie Substanz berenchet 71.82% C, 6.38% H und 21.8% O. Mit einem zweiten Präparate erhielt er aber sehr abweichende Zahlen 59.59% C, 7.02% H und 33.39% O als Mittel von 3 besser übereinstimmenden Analysen. T. wurde hiedurch veranlasst sein Präparat nochmals durch wiederholte Lösung in Aether- Alkohol zu reinigen, bis die Lösung nach 48 stündigem Stehen nichts mehr ausschied. Das so gereinigte Ericolin wurde dann während 12 Stunden bei 95° C getrocknet und eine Woche über Schwefelsäure gehalten. Es enthielt noch 0.32% Asche. Es wurdein feuchtem Zustande analysirt und der Trockenverlust, im Mittel 36.20% betragend und bei 95°-100° in gesonderten Portionen bestimmt, als Wasser in Rechnung gebracht. Er erhielt als Mittel aus 4 Bestimmungen:

82.46% C 5.89% H und 11.65% O.

Thal beschreibt sein Ericolin als geruchlos, braungelb, klebend hygroscopisch, stark bitter schmeckend, in Aether und Alkohol leicht, in reinem

(*) N. Tydschr. v. Pharm. in Nederland Jg. 1882 No. 11, Jg. 1883 No. 3 u. No. 8 wie auch New-Remedies Vol. XI, No. 10, Vol. XII, No. 3 u. 8.

Aether sehr schwer löslich. Beim Erhitzen schon unter 100° erleidet es eine teilweise Zersetzung unter Entwickelung von Ericinol. Es ist wenig in Benzol, noch weniger in Chloroform, leicht in Aether-Alkohol löslich und giebt bei der Spaltung durch Säuren Zucker und Ericinol. Letzteres wird sofort nach der Abscheidung teilweise oxydirt, teilweise in eine *Hydroericinol* genannte Substanz verwandelt.

Auf Grund von mehreren weiteren Elementaranalysen kommt T. zu dem Schlusse, dass dieses *Ericolin* bei der successiven Behandlung mit Benzin, Chloroform, Aether-Alkohol und Wasser schon eine teilweise Zersetzung erleidet unter Freiwerden von Ericinol, wie dies aus folgenden Data ersichtlich

		Asche	Verlust beim Trocknen	C%	H%	O%
I	*Reines Ericolin* (Thal)	0.32	36.20	82.46	5.89	11.65
II	Benzinrückstand „	0.—	24.40	78.23	8.13	13.64
III	Chloroform „ „	0.09	11.70	59.08	8.35	32.57
IV	Aether-Alkohol „ „	0.65	7.23	54.23	7.12	38.65
V	Ericolin (Schwarz. u. Rochleder)	10.65	—	51.71	7.19	41.10
VI	Pinipikrin (Thal)(*) aus H^a Sabinæ	0.47	13.43	57.46	8.33	34.21
VII	Pinipikrin (Kawalier) α aus Pinus silvestris	—	—	55.61	7.60	36.8
	β aus Thuya orientalis	—	—	55.45	7.62	36.93

Vergleichen wir diese Zahlen mit denen, welche ich fand für

Asebotoxin	0.—	—	60.48	7.4	32.12

so zeigen sie am meisten Aehnlichkeit, mit den Analysen III bis VII sind aber sehr abweichend von den Analysen I u. II welche mit Substanz angestellt wurden, welche beim Trocknen einen sehr grossen Gewichtsverlust (24.4-36.2%) zeigten.

Es war einleuchtend, dass der um so höher gefundene Kohlenstoffgehalt, je bedeutender der Verlust beim Trocknen, zum Teil daraus erklärt werden musste, dass die Substanz ohne weiteres Trocknen analysirt und dass der in einer gesonderten Probe bei 95°-100° bestimmte Gewichtsverlust als Wasser in Rechnung getragen wurde, während dabei nicht nur Wasser, sondern auch Ericinol verflüchtigt. *Thal* reducirt dem entsprechend auch die Resulte seiner Analysen (I) auf:

80% C, 7.69% H und 12.31% O

Zahlen, welche er berechnete aus der Formel $C_{26} H_{30} O_3$, welche bei Spaltung besser als die anfangs aufgestellte und aus den Analysen (I) berechnete Formel $C_{28} H_{24} O_3$ zu verwerten war. Leider standen mir nur die Nos. 14. 15. 17 u.

(*) Dieses Pinipikrin besass dieselben Eigenschaften und lieferte dieselben Spaltungsprodukte wie Ericolin.

18 der Pharm. Zeitschr. f. Russland Jg. 1883 zu Gebote und gelang es mir nicht das fehlende Heft anderweitig einzusehen, so dass ich auch die darin zu erwartenden Spaltungsversuche des Ericolins unerwähnt lassen muss.

Es fragt sich nun, ob auch für den giftigen Bestandteil der Andromeda Japonica Th. eine derartig leichte Zersetzbarkeit durch blosse Behandlung mit Lösungsmitteln wie Benzin, Chloroform etc. zutreffend ist, wie von Thal für das, wie mir scheint verwandte, Ericolin aus seinen Analysen abgeleitet wird. Es wäre möglich, dass das von mir, nach vielen solchen Behandlungen mit mehreren Menstrua, erhaltene *Asebotoxin* als Produkt einer teilweisen Spaltung des wirklichen Bestandteils aufzufassen sei und wären dann weitere Versuche und Analysen, wie sie von Thal mit dem Ericolin angestellt wurden, auch für das Andromedagift erwünscht. Leider scheint T. keine physiologischen Versuche über die toxische Wirkung angestellt zu haben, und darauf bezügliche frühere, Angaben konnte ich in der mir zur Verfügung stehenden Litteratur nicht finden, so dass ich auch in dieser Hinsicht keine Vergleiche zwischen dem Ericolin und Asebotoxin anstellen kann.

Nachdem ich wieder in Besitz einiger Verbrennungsröhren, gekommen war habe ich während des Drucks dieser Bogen noch einige Versuche und Analysen ausgeführt mit Präparaten, welche ich durch weitere Reinigung aus Resten, von früheren Reinigungsversuchen herstammend, erhielt.

A. Geruchloses, aschefreies Präparat, ein weisses Pulver bildend, in geschmolzenem Zustande schwach bräunlichgelb gefärbt. Mit conc. Salzsäure entsteht allmählich schöne Blaufärbung unter Verbreitung des früher erwähnten Geruches etc. Die wässerige Lösung, auch die in der Kochhitze gesättigte, reagirt völlig *neutral* und wird von Fe_2Cl_6 *nicht* gefärbt: mit verdünnter Schwefelsäure gekocht trübt sie sich weisslich, bald nimmt die Flüssigkeit rothe Farbe an, mit carminrothem Reflex, es scheidet sich eine anfangs wenig gefärbte ölige Flüssigkeit ab, die bei andauerndem Kochen grünlich, nachher braun wird und sich dann harzig abscheidet. Das Filtrat zeigte auch hier beim Kochen mit alkalischer Kupferlösung eine wenigstens gleichstarke Reduction wie die nicht vorher mit Säuren gekochte Lösung. In der Kälte zeigt es mit alkalischer Kupferlösung keine oder höchst geringe Reduction. 8 mgr., einem Kaninchen von 2.95 K°. Körpergewicht (= 2.7 mgr. p K°) in wässeriger Lösung subcutan injicirt, töteten innerhalb 2 Stunden unter den früher beschriebenen Symptomen. Das Präparat zeigte sich deshalb dem früher erhaltenen völlig gleich.

0.3668 gr. lieferten nach einstündigem Trocknen bei 105°-110° 0.3523 gr. Rückstand und 0.7974 gr. CO_2 und 0.2433 gr. H_2O.

oder 61.73% C
7.67% H
30.6 % O.

Ein ähnliches Präparat, in wässeriger Lösung neutral reagirend und mit Fe_2 Cl_6 schwache, zweifelhafte Färbung gebend, lieferte nach einstündigem Trocknen bei 110°

60.96% C, 7.56% H und 31.48% O.(*)

B. Ein fast reines Präparat., von dem vorigen darin abweichend, dass es in geschmolzenem Zustande mehr röthlichbraune Farbe zeigte, in wässeriger Lösung sauer reagirte und mit Fe_2 Cl_6 violettröthliche Färbung erzeugte.

0.4167 gr. lieferten während 1 Stunde bei c° 110° getrocknet 0.4120 gr. Rückstand und

0.2942 gr. H_2O und 0.9442 gr. CO_2

oder 62.5% C. 7.91% H und 29.59% O.

C. ähnliches Präparat wie B, in geschmolzenem Zustande noch mehr röthlich gefärbt. Die wässerige Lösung, welche es beim Verdampfen zurückliess, war anfangs völlig farblos, färbte sich jedoch während des Verdunstens röthlich.

Die wässerige Lösung reagirte stark sauer und gab mit Fe_2 Cl_6 ziemlich intensive Violettrothfärbung.

0.3715 gr., während einer Stunde bei 110° getrocknet, gaben 0.3425 gr. Rückstand und

0.7913 gr. CO_2 und 0.2336 gr. H_2O oder

63% C 7.6% H und 29.4% O.

D. Dieses Präparat war erhalten durch Fällung einer Lösung eines sauerreagirenden Präparates in Chloroform mit Petroleumäther, bis sich nichts mehr ausschied. Die Petroleumätherlösung wurde dann concentrirt und einmal mit Wasser ausgeschüttelt. Die abgehobene Petroleumätherschicht wurde verdampft und auf dem Wasserbade getrocknet. Der Rückstand war gelb gefärbt, klebrig zähe, löste sich in kochendem Wasser nicht völlig auf und verbreitete beim Trocknen in hohem Masse den betäubenden Geruch.(†)

Die wässerige Lösung reagirte ziemlich sauer und gab mit Fe_2 Cl_6 ziemlich intensive Violettrothfärbung.

0.4019 gr. während 1½ Stunden bei 105°-110° getrocknet gaben 0.3657 gr. Rückstand und

0.8904 gr. CO_2 und 0.2617 gr. H_2O oder

66.% C, 7.94% H und 25.66% O.

Durch subcutane Injection von 0.0002 gr. der Präparate A. B. C und D, in 1 Cm^3 Wasser gelöst, bei Fröschen wurde nun versucht, die relative Giftwirkung und Reinheit festzustellen. Wiewohl die Präparate A. B. und C keine grossen Unterschiede zeigten, war doch im Allgemeinen die stärkste Giftwirkung

(*) In diesen Präparaten findet sich die Bestätigung, dass das reine *Absebotoxin* in wässeriger Lösung neutral reagirt, was ich auch früher schon fand, doch bei dem damals analysirten Präparate weiter festzustellen vernachlässigte. Bloss den bei dem Ausziehen mit absolutem Aether zurückbleibenden Anteil habe ich auf seine neutrale Reaction controlirt.

(†) Es ist wohl diese flüchtige Substanz, welche den im Yudoku somoku susetsu erwähnten Kopfschmerz verursacht.

bei A und der Reihenfolge nach etwas schwächer bei B und C.

Das Präparat D. zeigte eine deutlich geringere Wirkung. Dass die Präparate A. B und C, wiewohl die letzteren durch ihre saure Reaction und ihr Verhalten gegenüber Eisenchlorid sich unrein erwiesen,(*) dennoch nur wenig Unterschied in toxischer Wirkung zeigten, scheint mir dadurch erklärlich, dass die Unreinigkeiten auch für sich nicht unwirksam sind oder vielleicht nur zu einzelnen Procenten in B und C vorhanden sind, sodass kleine Schwankungen in den Dosen bei Fröschen von verschiedenem Gewicht, 12-15 gr., und Individualität keine constanten Unterschiede in der relativen Giftwirkung zeigen.

Nach den Analysen zu urteilen würde eine grössere Unreinheit einem höheren Kohlenstoffgehalt entsprechen, doch sind Schwankungen, wie für die reinen Präparate gefunden wurden, von 60.3-61.7% C und 7.3-7.7% H, auch derart zu interpretiren, dass die analysirten Präparate, welche vorher schon unter dem Ersiccator oder durch Schmelzung auf dem Wasserbade teilweise getrocknet waren, nicht bis zum constanten Gewicht, sondern mit Rücksicht auf die Verbreitung eines besonderen Geruches nur während etwas 1 Stunde bei C° 110° getrocknet wurden.

Weil der Gewichtsverlust dabei nur 3-4% betrug, war die Verflüchtigung des eigentümlich riechenden Stoffes (Ericinol?) jedenfalls keine erhebliche und glaube ich daher, dass die angeführten Zahlen einen ziemlich genauen Ausdruck für die Zusammensetzung des *Asebotoxins* geben. Die von *Thal* weiter untersuchten, von *Rochleder* und *Schwarz* entdeckten, Körper Callutannsäure, Leditannsäure und Ledixanthin scheinen mir die Analoga zu den von mir abgeschiedenen Körper, *Aseboquercetin* etc. zu sein. Aus den Angaben von T. geht nicht hervor, in wie weit jene Körper die *Stein*'sche Paracarthaminreaction geben.

Scopolica Japonica Max. Längere Zeit, nachdem ich die Untersuchung dieser Pflanze abgeschlossen hatte, wurde mir eine kleine Probe gelber Krystalle übergeben mit der Bezeichnung *Solanin aus Scopolia Japonica* und welche schon vor mehreren Jahren dargestellt zu sein schien. Bei der Untersuchung stellte sich dieses Präparat als etwas unreines Scopoletin heraus. Es löste sich schwierig in Wasser, leicht in Ammoniak mit gelber Farbe und blauer Fluorescenz etc. und scheint somit das *Scopoletin* die Substanz zu sein, welche von Dr. Martin als Solanin aufgefasst und auch dieselbe, welche von Dr. Langgaard mit dem Namen Rotoïn bezeichnet wurde.

(*) In ihren sonstigen Eigenschaften verhielten sie sich fast gleich. Alle 4 Präparate gaben gesättigt wässerige Lösungen, welche sich mit Bleiessig (officinellem) klar mischen liessen und mit *Mayer's* Reagens milchartig weisse Trübungen gaben, welche auf Zusatz von etwa gleichem Volum Wasser wieder verschwanden. Auch reducirten sie ein Gemisch von Eisenchlorid und Ferricyankalium. Die Reaktion mit Salzsäure trat bei B und C etwas weniger rein ein als bei A.; bei D zeigte sich nur eine bräunliche Färbung.

TAFELN.

I *Andromeda Japonica Thunb.*

II *Scopolia Japonica Max.*

III *Scopolia Japonica Max.*, Wurzel und Querdurchschnitt

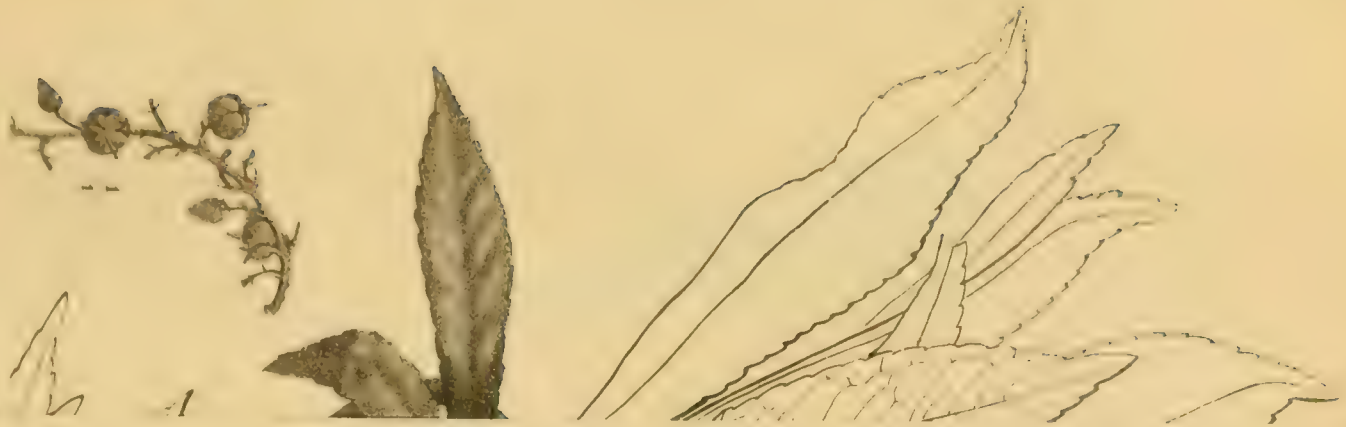
IV *Macleya cordata R. Br.*

V *Nandina domestica Thunb.* Exemplar in Frucht.

VI *Nandina domestica Thunb.* Blüthestand

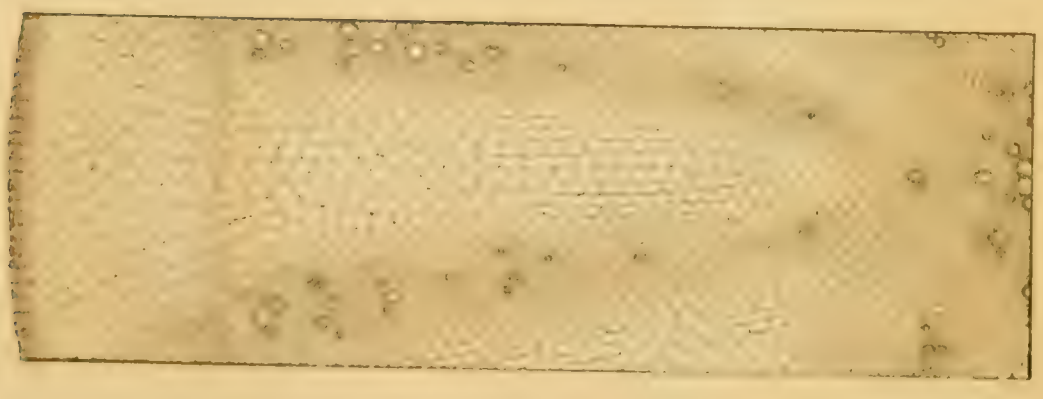
VII *Orixa Japonica Thunb.* mit Droge.

VIII *Skimmia Japonica Thunb.*



馬酔木

ANDROMEDA JAPONICA THUNB.



黃　芩　根

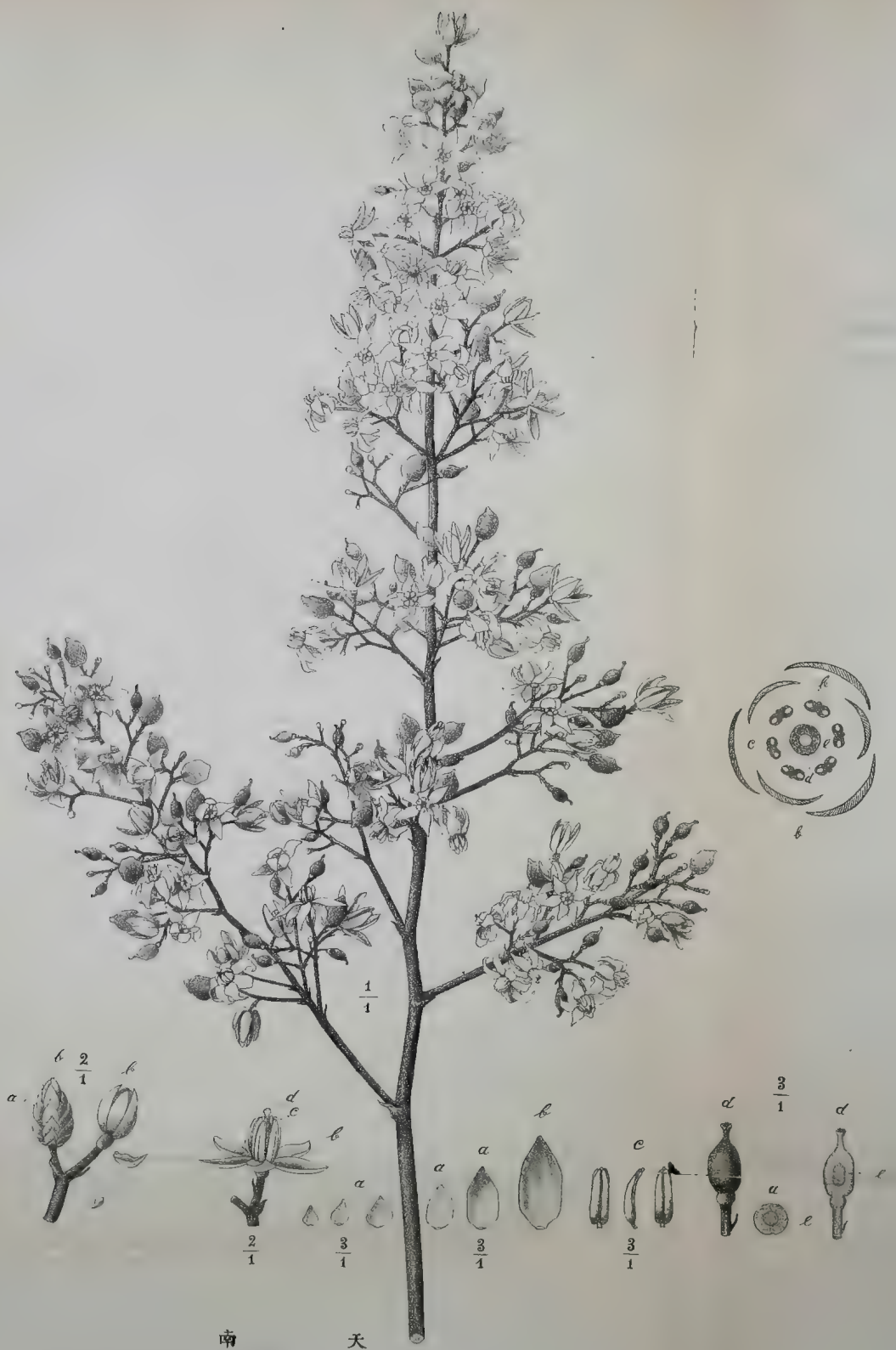
WURZEL DER SCOPOLIA JAPONICA.

博落迴

MACLEYA CORDATA. R. Br.

南　　天

NANDINA DOMESTICA THUNB.



南　　天

NANDINA DOMESTICA THUNB.

常　　山

ORIXA JAPONICA THUNB.

齒　　羊

SKIMMIA JAPONICA THUNB.

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